REPTILES AND AMPHIBIANS

By

THOMAS BARBOUR

/598.1B23>C1/

20221

598.1
B23

Barbour
Reptiles and amphibians

North Central College Library
NAPERVILLE, ILL.

Books, except reserve books, may be kept one week with privilege of renewal for like period, unless otherwise specified by librarian.

Five cents is charged for each day a book is kept overtime.

Reserve books may be drawn one half hour before closing and are due one half hour after the next opening of the library.

Five cents is charged for each hour a reserve book is kept overtime.

DATE DUE

MY 19'64
MAY 21 1971
0629'71
FE 4'72
MAY 2 6 1982

GAYLORD

PRINTED IN U.S.A.

REPTILES AND AMPHIBIANS

Their Habits and Adaptations

Digitized by the Internet Archive
in 2024

https://archive.org/details/reptilesamphibia0000thom

FIG. 19. AN IGUANA LIZARD OF SWAN ISLAND, OFF HONDURAS (*page* 15)

REPTILES AND AMPHIBIANS

THEIR HABITS AND ADAPTATIONS

BY

THOMAS BARBOUR

Curator of Reptiles and Amphibians in the Museum of Comparative Zoölogy at Harvard College

ILLUSTRATED IN PART BY

GEORGE NELSON

Preparator in the Museum of Comparative Zoölogy

LIBRARY

BOSTON AND NEW YORK
HOUGHTON MIFFLIN COMPANY
The Riverside Press Cambridge
1926

COPYRIGHT, 1926, BY THOMAS BARBOUR

ALL RIGHTS RESERVED

The Riverside Press
CAMBRIDGE · MASSACHUSETTS
PRINTED IN THE U.S.A.

598.1
B23

IN APPRECIATION
OF THE ENCOURAGEMENT
GIVEN TO SCHOLARS
BY THE
LOWELL INSTITUTE
OF BOSTON

20221

PREFACE

In this volume I have tried to set forth as simply as possible the various modifications both in form and in habits which living reptiles and amphibians have acquired, by evolutionary processes, to enable them the better to meet varied environmental conditions. It is not a complete or detailed account, but may be — I hope it is — suggestive.

Increasing interest in tropical regions, with the establishment of well-ordered research stations in the tropics, is now making it possible for the younger teachers to be familiar with life in the jungle, and we may expect — indeed, we already see — young students gleaning a rich harvest in regions which once were thought to be reasonably well known. Such rapid advances are being made in our knowledge of life-histories that far more information is to be expected in the next decade, concerning habits of amphibians especially, than has accumulated up to the present time.

Part of the material for this book was gathered for a course of lectures in the Lowell Institute of Boston given in October, 1923.

CONTENTS

	Introduction	xvii
I.	Origin, Present and Past Distribution	1
II.	Size and Food Value	11
III.	Concerning Poisons and Poisonous Snakes	19
IV.	Control of Poisonous Snakes	26
V.	The Fang, its Origin and Function	29
VI.	The Poison	33
VII.	Effects of Feeding Habits on Dentition	38
VIII.	Protective Devices of Snakes — Abnormalities	40
IX.	Adaptations of Lizards	53
X.	Adaptations of Lizards (*continued*)	62
XI.	Adaptations of Frogs	69
XII.	Adaptations of Frogs (*continued*)	82
XIII.	The Urodeles or Salamanders, and the Cæcilians	97
XIV.	Superstitions	101
XV.	The Work of Evolution	103
XVI.	Conclusions	108
	Annotated Bibliography	109
	Index	119

ILLUSTRATIONS

The numerical order of the figures in each plate is from left to right and from top to bottom, as the page of a book is read. In every case where no credit is given the illustration is from a photograph by G. Nelson.

19. Iguana, Swan Island — *Frontispiece*

1. Geological Time Chart — 2

2. An Ichthyosaur — 4
Photograph from American Museum of Natural History, New York

3. Brontosaurus — 4
Photograph from American Museum of Natural History, New York

4. Tyrannosaurus — 4
Photograph from American Museum of Natural History, New York

5. Plesiosaurus — 4
Photograph from American Museum of Natural History, New York

6. Ornithomimus — 5
Photograph from American Museum of Natural History, New York

7 A Fossil Pterodactyl — 5
From a specimen in the Museum of Comparative Zoölogy, Cambridge, Mass.

8 Sphenodon — 5
Photograph from American Museum of Natural History, New York

9 Anolis nelsoni from Swan Island — 8

10. Tropical Rain Forest — 9
Photograph by T. Barbour and W. S. Brooks

11 A Bahama Island Shore — 9
Photograph by T. Barbour

12. Reticulated Python — 12
Photograph by Sanborn, New York Zoölogical Society

13 Galapagos Tortoise — 13
Photograph from New York Zoölogical Society

14. Varanus komodoensis — 13
Photograph published by Major Ouwens, of Buitenzorg, Java

15. An Alligator 14
Photograph published in a Sunday supplement
16. Giant Crocodile Skull 14
17. Phyllobates limbatus 15
18. Rana goliath 15
20. Loggerhead Sea Turtle 20
21. Turtle Eggs 20
22, 23. Heads of Pit Vipers 21
24. The Gaboon Viper 21
Photograph by Lang, Congo Expedition of American Museum of Natural History
25. Head of Same 21
Photograph by Lang, Congo Expedition of American Museum of Natural History
26. The Serpentarium at Butantan 26
Photograph from Instituto de Butantan
27. Mongoose Killing a Cobra 26
Photograph by T. Barbour
28. Brazilian Skunk 26
29. Musurana Eating a Viper 26
Photograph from Instituto de Butantan
30. Head of Cobra 27
31, 32. Fang Movement in Viper Skull 27
33. Dissected Rattlesnake Head 27
34. Extracting Snake Poison at Butantan Institute, Brazil 34
Photograph from Instituto de Butantan
35. Copperhead 34
36. Skull and Jaws of a Python 35
37. Skull and Jaws of an Iguana 35
38. Diagrams of the Rattle of the Rattlesnake 35
After Garman
39. The Rattle of the Rattlesnake 35
40. A Python which has Swallowed a Pig 40
Photograph by Prof. H. W. Smith, taken in Malaya
41. African Tree Viper, Atheris 41
Photograph by Lang, Congo Expedition of American Museum
42. Spreading Adder, Heterodon 41

43. Indian Cobra 41
Photograph by T. Barbour

44. Theletornis Spreading its Neck 41
Photograph by Lang, Congo Expedition of American Museum

45. Cylindrophis with Tail Erect 48
Adapted from N. Annandale

46. Doliophis with Tail Erect 48

47. Poison Gland of Doliophis 49

48, 49. The River Jack of West Africa 49
Photograph by Lang, Congo Expedition of American Museum

50. A Sea Snake 50
Photograph from New York Zoölogical Society

51. Axial Bifurcation in Lampropeltis 50
Photograph from New York Zoölogical Society

52. Marine Iguanas at Galapagos Isles 51
Photograph by R. H. Beck, California Academy of Science Expedition

53. Galapagos Land Iguana 51
From William Beebe's Galapagos, World's End, by permission of the publishers

54. Basiliscus 54
Photograph from New York Zoölogical Society

55. Læmanctus 54
Photograph from New York Zoölogical Society

56. Clamydosaurus Running 55
Photograph by Saville Kent

57. Callisaurus Running 55
Photograph by H. Lang. From Bulletin of New York Zoölogical Society

58. A Desert Skink Lizard 55

59. Chlamydosaurus at Bay 56
After Boulenger

60. Feet of Ptenopus and Uma 56

61. Cachryx 56

62. Uromastix 56

63. The Australian Moloch 57
After Saville-Kent

64. A Zonurus 57
65. An African Chamæleon 58
66–70. Heads of African Chamæleons 58
71. A Gecko 59
Photograph by Lang, Congo Expedition of the American Museum
72. Foot of the Gecko, Ptyodactylus 59
73. Palmatogecko 59
After L. G. Anderson
74. Phyllurus 60
75. Nephurus 60
76–78. Tail Regeneration 61
79. Skeleton of Reproduced Tail 61
80. Ptychozoon 66
81. Draco vølans 66
82. The Gila Monster 66
83. Anolis nelsoni at Display 66
84. A Typical Pond Frog 67
85. A Typical Upland Toad 67
86, 87. Tree Frog and Fingers 70
88. An African Tree Frog 70
Photograph by Lang, Congo Expedition of the American Museum
89. Clawed Frogs, Xenopus 71
Photograph from New York Zoölogical Society
90. Hymenochirus 71
91. Telmatobius æmaricus 72
92. Telmatobius culeus 72
93. Telmatobius (or Batrachophrynus) microphthalmus 72
94–96. Three Ant-Eating Toads 73
97. Head and Tail of Uropeltid Snake 73
98. Bufo empusus 74
99. Tree Frog Closing Entrance to its Lair 74
100, 101. Pseudis 74
Drawing after Garman
102. Dagger Frog's Thumb 76
103. Hairy Frog, Astylosternus 75
After Boulenger

104. Various Tadpoles 78
105. Ponds of Hyla faber 78
After Goeldi
106. Breeding Nest of Hyla resinifictrix 78
107, 108. Chiromantis and Nest 79
The frog from photograph by Lang, Congo Expedition of the American Museum. The nest is in the Museum of Comparative Zoölogy, taken by A. Loveridge in Tanganyika Territory, East Africa
109. Phyllomedusa Nest 80
110. Hylambates (or Leptopelis) aubryi 82
Photograph by Lang, Congo Expedition of the American Museum
111. Nectophryne 82
Photograph by Lang, Congo Expedition of the American Museum
112. Dendrobates Carrying Tadpoles 83
Photograph by C. William Beebe at Kartabo, British Guiana.
113. Rhinoderma with Tadpoles in Vocal Pouch 83
114. Pipa, the Surinam Toad 86
115. Skin of Back of Pipa Enlarged 86
116. Hyla evansi Carrying Eggs 87
Photograph by H. Lang, American Museum
117. Hyla goeldii of Brazil 87
After Boulenger
118, 119. Marsupial Frog and Young 87
The young after Boulenger
120. Hyla vasta 92
Photograph by Dr. G. K. Noble, American Museum
121. Bombina in Warning Attitude 92
122. Dendrobates tinctorius 92
123. Schlegel's Tree Viper 93
124. Megalophrys nasuta 93
After Boulenger
125. Veranus Feigning Death 94
Photograph by Lang, Congo Expedition of the American Museum
126. Heterodon Feigning Death 94
127. King Snake Coiled into a Ball 94
128, 129. Bufo superciliaris, at Rest and Feigning Death 95
Photographs by Lang, Congo Expedition of the American Museum

130. Giant Salamander of Japan 96
After Schlegel, Leyden, 1833

131. Siren 97
Photograph from New York Zoölogical Society

132. Amphiuma 97
Photograph from New York Zoölogical Society

133. Male and Female European Newt (Triturus) 98
After Boulenger.

134. Necturus 98
Photograph from New York Zoölogical Society

135. Axolotl 98
Photograph from New York Zoölogical Society

136–138. Eggs, Larva, and Brooding Adult of Cæcilian 99
After Saracin

139. Coach-Whip Snake 99

140. A Water Snake 99

141, 142. Snake 'Charmers' in India 102
Photographs by T. Barbour

INTRODUCTION

My desire in this little book is to present such general considerations regarding Amphibians and Reptiles as may cause them to be considered with less aversion and may incline my readers to examine them with greater interest and a more kindly feeling than many have had in the past. I shall try to answer the questions that are most often asked me, and to avoid a consideration of the technical relationships, although some allusion to classification is not only desirable but inevitable.

Since, then, this is in no wise intended to be a systematic treatise, I have scarcely defined and not described either species or the larger groups. I have perforce assumed that my reader has learned, either from observation or reading, the limits and characters of the principal subdivisions of the Reptilia and Amphibia. Thus I speak of geckos and iguanas; of hylid, befonid, or ranid tree frogs, of toads and pond frogs without ado. The meaning of such terms is easily to be found, and promising hunting ground for such information is indicated in the bibliographic section.

I have endeavored to write as simply as I can. I feel more and more that it is no light task to treat a discussion of these adaptations in what is currently termed 'popular language.'

Reptiles, in comparison with birds and mammals, measure the lesser degree of popular interest which they inspire by the small number of popular names which they have received. This, curiously enough, is particularly striking in civilized communities, while in the areas where, for instance, Malay is spoken, or Tupi-Guaraní in South Amer-

ica, or Lepcha in the Himalayan foothills, the languages are rich in reptile names. But this does not help *us*. We have no choice but to use scientific names where no others are at hand. These names, unfortunately, are seldom euphonious and are accompanied by a sort of aura of pedantry.

It is not intended that this shall be a complete textbook of herpetology, for it obviously lacks a definite continuity of thought and only selected topics are discussed.

The living reptiles include crocodilians, a single Rhynchocephalian relict, tortoises, lizards, and snakes. The known Amphibians are worm-like cæcilians, lizard-like newts, and the jumping forms — frogs and toads.

The Crocodilia, comprising crocodiles, alligators, and the South American caymans, differ from other reptiles in that the ventricle of the heart is completely divided, and there is a muscular diaphragm between the thoracic and abdominal cavities. There are other less fundamental divergences.

The Sphenodon of New Zealand is the last remnant of an ancient order once widespread and abundant, the Rhynchocephalia. It differs from existing reptiles by lacking any copulatory organ and by the possession of a plastron of 'abdominal ribs' of very complicated character.

In all the tortoises, [1] land, fresh-water, and marine, the body is enclosed in a bony shell. The animals are sharply divided into two groups: those which retract the head by an S-shaped flexure of the neck and those which protect the head by laying the head and neck sidewise under the overhanging edge of the shell.

The lizards, or Lacertilia, are those forms having the typical reptilian heart with undivided ventricle, the rami

[1] Tortoise, a wide generic term; turtle, a marine or fresh-water tortoise; terrapin, certain American fresh-water species. The names are all loosely applied.

of the lower jaw united by suture, no shell about the body, and possessing paired copulatory organs. This group is again divided into the true lizards (Lacertilia vera) with flat tongues, and the African chamæleons (Rhiptoglossa) with tongues enormously extensile.

The snakes, or Ophidia, are sharply set off from other reptiles in that the branches (rami) of the lower jaw are united by a ligament and not by suture.

Amphibia differ from Reptilia in that they normally pass through a larval stage. Their skin is soft, slimy, and scaleless.[1]

The Cæcilians are limbless and worm-like.

The Urodela[2] (newts, salamanders, etc.) are tailed in the adult stage.

The Salientia are not tailed in the adult, although the larval (tadpole) stage possesses a tail.

Such in merest outline is the classification of the groups which are to be discussed. Since the elaboration of these diagnoses can be learned from any textbook of zoölogy, they will not be expanded. The later treatment of some groups, such as snakes and lizards and to some extent the amphibians, makes it necessary to discuss some of the families within these orders at some length, and therefore the schemes to show the interrelationships of these groups have been given. In general, however, definitions are avoided, but may be found as indicated in the annotated bibliography.

Zoölogists use to-day what is called the Binomial Nomenclature. This consists first of a generic name, always written with a capital letter, followed by a specific name, always written with a small letter, and to this is added

[1] There are, of course, many other anatomical differences in each of these cases.

[2] In Gadow's *Amphibia and Reptiles*, of the Cambridge Natural History Series, keys and definitions of the various families may easily be found.

the authority who first proposed the species. This system dates from the tenth edition of the *Systema Naturæ* of Linneus, published in 1758. Recently it has been found advisable to recognize geographic races or subspecies. These are introduced as trinomials.

Some of the larger groups, especially families and subfamilies, are named automatically according to certain definite rules and have characteristic suffixes, the name of a family ending in 'idæ' and of subfamilies in 'inæ.'

The original specimen from which a species is described is called the 'type specimen' and such examples carefully preserved are always the standard of comparison when questions of identity are involved.

To take a concrete example, the name for Edward's Ground Rattlesnake is *Sistrurus catenatus edwardsii* (Baird & Girard). The classification running down to this particular geographic race would then be as follows:

Vertebrata — phylum
Reptilia — clan
Squamata — order
Serpentes — suborder
Crotalidæ — family
Crotalinæ — subfamily
Sistrurus — genus
catenatus — species
edwardsii — subspecies
(B. & G.) — authority

REPTILES AND AMPHIBIANS

REPTILES AND AMPHIBIANS

CHAPTER I

ORIGIN, PRESENT AND PAST DISTRIBUTION

According to the estimate of geological time now generally agreed upon, reptilian life has probably been present upon the earth some ninety million years or more, and the appearance of Amphibia took place probably at least three or four million years earlier — a vast time, indeed (Fig. 1). Nothing is more difficult to cultivate than the capacity to appreciate the infinity of space and the near-infinity of time which sane modern astronomical and geological discoveries indicate. This is not the place to consider the vast changes in the earth's crust which have taken place since the dawn of animal life on this planet, but there have been great changes in the relative distribution of land and water even in comparatively recent geological times and parts of the earth are still in unstable equilibrium, as shown by the frequent earthquakes. It is in studying these changes in land form that the zoölogist may, by analyzing the fauna, aid the geologist and check his conclusions.

It is only recently that it has been possible to conclude with some precision whether the components of a given insular fauna, for instance, have been fortuitous waifs carried hither and yon with the ocean's 'flotsam and jetsam,' or have been involuntary companions of man during his early voyages and migrations, or whether some land connection must be assumed to account for the animals' presence upon the isle. This appraisal requires close study of

ways of living, breeding habits, resistance to environmental change, feeding habits, and other factors in life-history. Thus a fascinating field-pastime may have most useful ap-

FIG. 1. DIAGRAM SHOWING THE RELATIVE IMPORTANCE, *i.e.* THE RELATIVE DURATION, OF THE SEVERAL RECOGNIZED GEOLOGICAL PERIODS WHEREBY THE ERAS OF TIMES PAST ARE DESIGNATED

plication in aiding geographic interpretations. Not that such useful application should be considered as thereby more greatly justifying the observations, but they do by chance serve a practical purpose.

This field of zoögraphy or zoögeography, as it is more often called, offers countless opportunities to the voyaging amateur to add to the sum of knowledge.

Now to return to our subject: Since the forerunners of all the great groups of animals were usually small, weak, and delicately formed creatures, the earlier members of each group are far less adequately preserved as fossils than are the later gigantic terrestrial types. Thus we know little of the primitive amphibians and not much more of the very earliest reptiles, nor is future exploration likely ever to open the door very widely. The tortoises and crocodiles, for instance, among recent types, naturally are especially to be excepted; their heavier bones as well as their fluviatile or lake-dwelling life have conduced to their more abundant preservation, but they represent a relatively advanced development.

There can be no doubt that the Amphibia sprang from the fishes and gave rise to the reptiles. The group has thus an intermediate position. Not that any recent amphibians can make such a claim; for the frogs, the newts, and the legless cœcilians, representing the three persisting amphibian groups, are far too specialized. But the ancient ancestral order of the Stegocephalians showed such a relationship. They were large, short-legged, partially armored, lizard-like animals, no survivors of which remain. These creatures appeared in Carboniferous times, throve and developed, reaching a large size and multiplying abundantly, only to disappear completely in the Upper Trias. Of existing amphibians the cœcilians are unknown in a fossil state; the Anura, or the group comprising frogs and toads, are known from the Jurassic, but are very rare as fossils. These early frogs, however, are just as typically true jumping frogs as any now existing, so that we must search even earlier for intermediate ancestral stages. The tailed forms, newts and salamanders, being very delicate, have been but poorly preserved, and only one Mesozoic

and a few Oligocene, Miocene, and Pliocene types are known.

The reptiles have had a similar but far more elaborate history. Appearing in the lower Permian, they reached a marvelous culmination in development during the Jurassic and Triassic, but since then they have steadily waned. At their period of maximum development they invaded the oceans, and porpoise-like reptiles were common (Fig. 2); they attained to flight, and bat-like reptiles appeared, ranging in size from that of a sparrow to that of a wandering albatross (Fig. 7).

Bulky herbivorous forms larger than elephants (Fig. 3) — the African Gigantosaurus was 180 feet long — were preyed upon by gigantic carnivorous allies (Fig. 4), if less in size yet far more active. Others ran upright, their fore limbs shrunken to little plucking paws (Fig. 6). But these old dinosaurs have become familiar to all and now garnish frequently the Sunday supplements and serve other advertising purposes, as well. These have all disappeared. Whether or not because with the appearance of mammals their eggs offered easily found and gargantuan meals is uncertain. But they waned nevertheless far more rapidly than they had previously risen to the elaborately adaptive radiation which they displayed at the time of their maximum abundance. Their remains are numerous and widespread; vast numbers of their bones have been recovered and restored from East Africa, north-central Asia, and western North America.

There remains only one conspicuous reptilian 'living fossil,' the curious Sphenodon (Fig. 8) of New Zealand now preserved on Stephen Island in Cook Straits; the sole survivor of the ancient Rhynchocephalia, a group which in Permian times gave rise, not only to lizards and crocodiles,

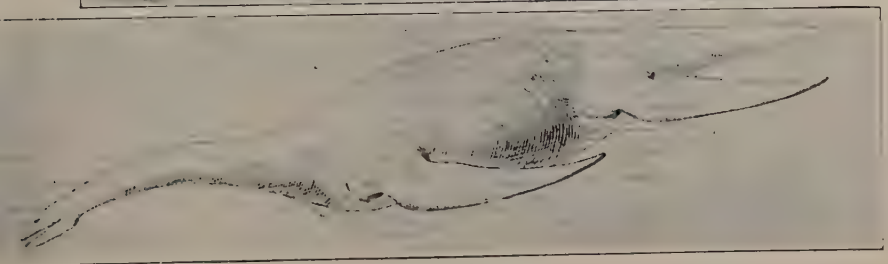


FIG. 2. ICHTHYOSAURUS, A PELAGIC PORPOISE-LIKE REPTILE

FIG. 3. BRONTOSAURUS

FIG. 4. TYRANNOSAURUS

FIG. 5. PLESIOSAURUS, A PREDACIOUS AQUATIC TYPE WHICH HAS COMPLETELY DISAPPEARED

FIG. 6. ORNITHOMIMUS, A BIPEDAL SAUROPOD DINOSAUR

FIG. 7. A FOSSIL PTERODACTYLUS. AGE JURASSIC

FIG. 8. SPHENODON, THE FAMOUS LIVING RHYNCHOCEPHALIAN OF STEPHEN ISLAND, NEW ZEALAND

but to that marvelous group, the dinosaurs, as well, and perhaps even to the birds. No other stock can claim so many and so diverse descendants.[1]

It is customary to call snakes 'primitive' and 'degenerate' because they seem relatively simple in appearance. In fact, however, they represent extreme modification, whereas the apparently more highly organized and really ancestral lizards seem to the average observer a 'higher' type of development. Lizards are simply to be considered the more generalized, more typical or less modified group of the vertebrates from which the snakes have sprung.

All those reptiles which actually flew, or which were highly specialized for a marine life, as, for example, the Plesiosaurs (Fig. 5) have long since disappeared and the only single type which now relies upon the ocean for food is Amblyrhynchus (Fig. 52), the marine iguana of the Galapagos Islands. As is described elsewhere, this lizard visits the sea cliffs at low tide to feed on algæ and it is often wet by the waves themselves.

It is not improbable that Central Asia was the region where most of the great groups had their first rise to prominence and whence they spread widely under the far different geological conditions which prevailed long ago; for the isolation of the continents as we now observe them has been (geologically speaking) but recently brought about and many facilities for migration existed in the past which are not now to be found. For instance, there were land bridges, some still in dispute, but some universally agreed upon. Only a slight change in the relative relation between land

[1] This view is not shared by Williston in his masterly posthumous *Osteology of the Reptiles*, which has just appeared. He believes that the Rhynchocephalians have given rise to the alligators and their allies among recent reptiles, but not to the snakes and lizards, which he puts in a separate subclass. His views will probably be widely accepted in the future.

and sea level would suffice to dry the straits between Alaska and Siberia. Indeed, this strait was dry but a short time ago. Similarly the connection of the East Indies with continental Asia is equally certain. Many other 'land bridges' require a postulate of more fundamental changes in the earth's sculpture, and here we find disagreement among authorities. The strong trend of opinion at present, however, is to listen with far more sympathy to explanations of existing distribution based on fundamental changes in the form of the present land masses than would have been customary a generation ago. This topic is one that cannot be elaborated in this small book, nor yet even outlined in a few words. The bibliography indicates where the curious reader may begin an exploration of the maze of zoögraphy.

Nevertheless, it must constantly be borne in mind that many of the groups of reptiles now existing were formerly much more widespread than they are now. Crocodilians, for instance, abounded in the fresh-water lakes of what are now our Middle-West States, and many of the conspicuous tropical groups of lizards were present in what is now Europe and the United States.

While there are a few garter snakes on the plains of northern Alberta and a few vipers on the lower Siberian steppes, it is evident that these are recent invaders. Even in the temperate regions of the globe, where there is a definite winter with frozen ground, reptiles are few, not only in species, but usually in individuals as well. In these regions, also, man — civilized man — kills snakes wherever and whenever he finds them, and many species are growing rare and difficult to find. In regions fast being settled, like peninsular Florida, where road-building is rapidly carried on, motor cars account for the death of many thousand

snakes a year, for they are run over as they stretch out in the grateful warmth of the open road to 'take the sun,' as the Spaniards say. So also box tortoises are becoming rare, indeed are almost extinct in southern New Jersey and Cape Cod, where the same treatment is accorded them. I have motored many times over the highway along several hundred miles of southeastern Florida in almost every one of the few years since there has been a passable road. Eight years ago the road between Palm Beach and Jupiter was quite new, and freshly killed snakes were seen in numbers. I remember once, after a brisk shower, seeing nearly thirty 'glass snakes' in the road on one ten-mile stretch. Most of these had been killed at once. This year (1924) in April, a favorable season, on a three-hundred-mile trip not half a dozen snakes were seen. The motor is the snakes' worst enemy, as it is the turtles'. The road is always too tempting as a basking ground.

Happily these conditions do not obtain the whole world over, and in the roadless tropics reptiles abound, not everywhere, to be sure, but in some places they actually swarm. Anolis lizards (Fig. 9) in the Bahamas, and the little slippery skinks [1] in Papua are, I believe, the most teeming reptiles on the globe. The environmental conditions of these two localities are as different as night is from day. Papua with dense dark forests, so high and so gloomy, as to make one feel the same sense of one's own insignificance as does a high canyon wall. The air of Papua is moist, the forest floor sodden and mouldy, but every little spot of sunlight which leaks through the high leafy roof is alive with hordes of tiny smooth and brilliantly colored lizards, all of the family Scincidæ (the skinks) and legion in species as in individuals. In the rain forest (Fig. 10) of tropical America,

[1] Skink, any member of the Scincidæ, a cosmopolitan family of lizards.

which is quite as fine as that of Papua or Indo-Malaya, no such hordes of reptiles are to be found; for while there are many species and some of them are common, they usually require much diligent hunting on the part of the naturalist before he secures the series he needs for study.

The Bahamas (Fig. 11) are semi-arid, low-lying, with a scanty vegetation, and in summer are almost unbelievably hot. But the little Anoles, allies of our so-called Florida chamæleon, pose and bob their heads at each other, expanding their brilliant dewlaps, till one wonders why they do not dry up and blow away, for it is said that the sun temperature reaches 150° or 160° which often seems no exaggeration.

In the warmer parts of the earth reptiles are found in all situations: deserts, grassy plains, hills, and forests all have their quota of species; some sharply restricted to one sort of environment and very local, others ranging widely and evidently able to live and thrive under very varied conditions. Many of the oldest and least adaptable types have extraordinarily circumscribed ranges. Thus, Cricosaura in Cuba, a distinctly archaic little lizard, seems to be absolutely confined to a zone of coastal plain near Cabo Cruz. Indeed, its whole range is but a few hundred acres so far as is now known. So, too, the species of the family Xantusiidæ in our Southwest have a very limited distribution indeed. These archaic and 'disappearing types' have almost universally become nocturnal. The opposite extreme is to be seen in the case of one of the strong, active African monitor lizards (*Varanus*[1] *niloticus*), which is found over almost the whole of Africa with the exception of the very arid northwestern portion of the continent. Between such extremes there is every possible intergradation of dispersal.

[1] Cf. Fig. 14 of a related species *Varanus komodoensis*.

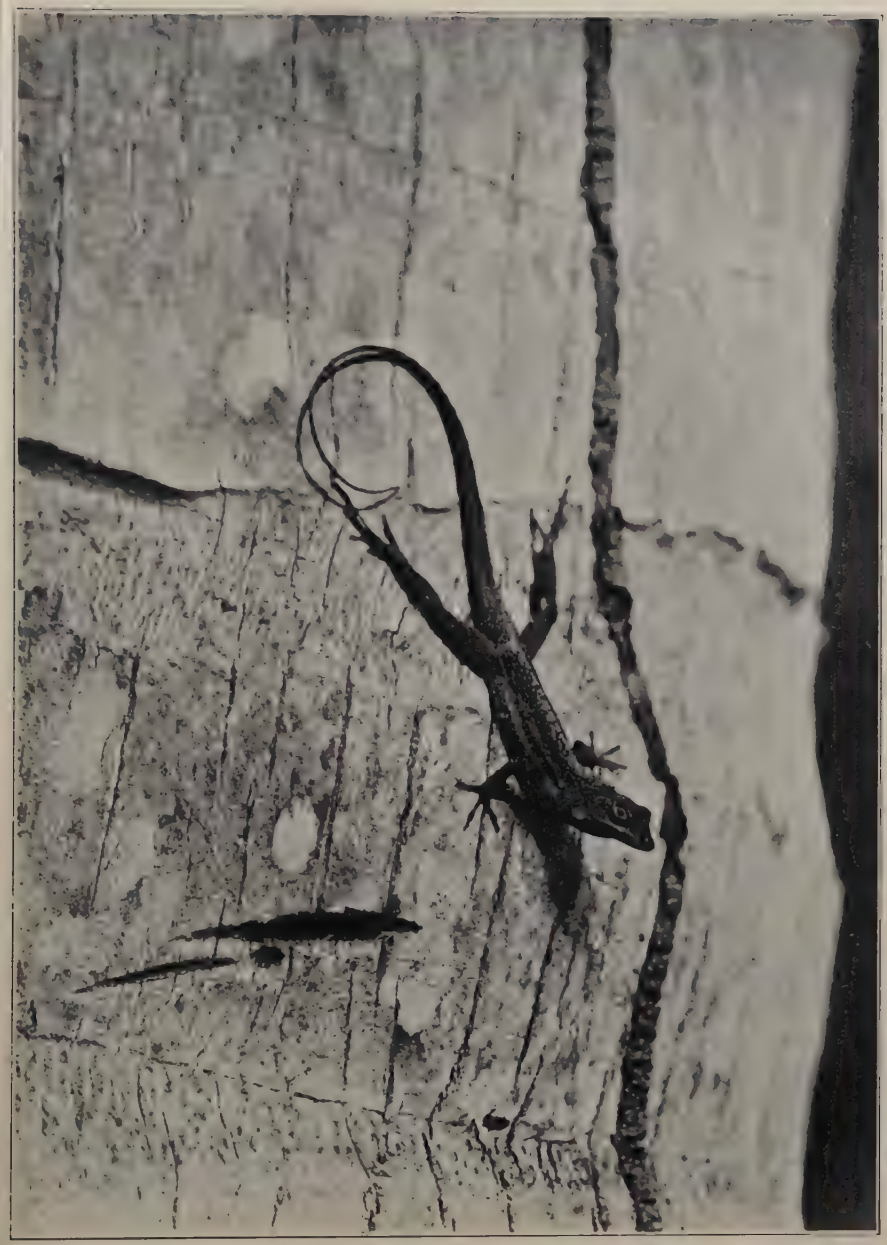


FIG. 9. ANOLIS NELSONI WATCHING FOR WHITE ANTS AS THEY PASS A BROKEN PLACE IN THE COVERED GALLERY TO THE RIGHT. THE PHOTOGRAPH TAKEN ON THE TRUNK OF A COCONUT PALM ON SWAN ISLAND OFF HONDURAS

FIG. 10. THE HIGH RAIN FOREST OF EASTERN PANAMA IN THE SAPO MOUNTAIN REGION

Perhaps the most varied forest in the world, surely one of the most luxuriant.

FIG. 11. THE SHORE OF GREAT ABACO ISLAND IN THE BAHAMAS

The islands, being sterile, support a rather meagre flora.

Naturally species, which, for instance, are highly modified for burrowing in sand or for life in the tree-tops, are found only in deserts or in forests. Representatives of many different types of both reptiles and amphibians have become more or less aquatic as well as arboreal, and many striking adaptations have arisen to fit them for life in water or forest. A discussion of these modifications is to be found in later chapters.

Many amateurs of herpetology or of the study of reptiles do not realize that there are legless lizards, and hence often confuse them with snakes. In several cases they are superficially very similar one to the other. The lizards generally have movable eyelids, which no snake possesses, and, moreover, always have the bones of the lower jaw fused together at the symphysis (chin), whereas the snakes have these bones separate except for a more or less flexible ligamentous attachment. There are, of course, many other morphological characters which separate them, but by this means the field observer may easily distinguish with which he is dealing.

Number of species. Few students except those who specialize in systematic zoölogy realize how very many species of reptiles and amphibians there really are. We may speak in round numbers only, for new ones are constantly being found.

There are definitely twenty different crocodiles, including their close cousins the South American caymans and the alligators of our South and of the Yang-tze River in China.

There are about 225 kinds of tortoises and turtles, land, fresh-water, and marine.

Of snakes, there are about 2300 different sorts; of lizards probably about 2500; while of amphibians there are about

1500 frogs and toads, about 150 newts and salamanders, and about 50 of the curious blind worm-like cœcilians, the latter unknown except to the specialist. To these we must add Sphenodon (Fig. 7) (one species) from New Zealand.

CHAPTER II

SIZE AND FOOD VALUE

Questions about the largest snakes are difficult to answer. The tales of the Amazonian voyagers who say that they have seen snakes fifty or sixty feet long are hard to believe. Yet there is no doubt that there are larger Anacondas in the Amazon and its tributaries than have yet been caught, especially about the great swampy Ilha de Marajó which lies at the Amazon's mouth. These snakes *may* reach the reported maximum of fourteen metres (forty-six feet). It is doubtful if this is ever much exceeded. A specimen of this size has been credibly reported to Dr. Afranio do Amaral, the principal authority in South America. No such specimen has ever actually been saved, though a ten-metre skin is preserved at Butantan in Brazil. The author has seen a Malayan python twenty-nine feet long, and another twenty-seven feet long There are at least two now in captivity in America which are over twenty-five feet. Charles Meyer, a professional collector of living animals, is said to have caught in the State of Negri Sembilan in Malaya a python (Fig. 12) thirty-two feet long, which he took alive to Europe.

Rattlesnakes grow to great size in Florida and on the dry plains of southern Texas, but the great majority of the species and those that are probably most primitive in their characteristics are not very large or very dangerous.

The longest poisonous snake is the king cobra (*Hamadryas hannah* Cantor) of southeastern Asia, which, though relatively light and slender, reaches eighteen feet in length. The mambas (Dendraspis) of Africa are also long and very whip-like.

The heaviest poisonous snake is the bushmaster (*Lachesis muta* Linné) of Central and South America, which is known to grow to be eleven or twelve feet in length and is a powerful and muscular species. It is not impossible that a Florida rattlesnake (*Crotalus adamanteus* Beauvois), nearly eight feet long, of which I have the skin, might have weighed even more than a full-grown bushmaster.

Sea turtles grow to a far greater size than land turtles. The great leather-back sometimes weighs nearly half a ton. The giant land tortoises (Fig. 13) of the Mascarene Islands and the Galapagos probably never weigh over five hundred pounds, and these are probably as large as any land tortoises have ever been, except the fossil Colossochelys of India.

The largest living lizard has only very recently been discovered. For years Malay tales of a land crocodile had been heard from travelers in the Lesser Sunda Islands near Flores and Timor. Finally, one was secured and proved to be a veritable giant among lizards (Fig. 14). It reaches a size of no less than thirteen feet and is said to grow to twenty feet or more. The new species was named *Varanus komodoensis* by Major P. A. Ouwens, late Director of the Buitenzorg Museum in Java. These lizards live in caves in the hills of Komodo and other small islands near Flores, from which they issue to hunt mammals and birds and other lizards. Since this lizard is agile and swift in its movements, one can easily appreciate the terror which it inspires among the natives. The astonishing thing is that so large a creature passed wholly unnoticed until about ten years ago.

Alligators are reported to reach sixteen feet, but such specimens are excessively rare to-day. One was recently reported from Louisiana to measure eighteen feet six

FIG. 12. THE RETICULATED PYTHON OF MALAYA

One of the largest snakes if not the very largest snake in the world. This half-grown specimen is about ten feet long.

FIG. 13. A GIANT TORTOISE FROM THE GALAPAGOS ISLANDS
Shows the characteristic way of placing the apparently clumsy and heavily armored feet.

FIG. 14. VARANUS KOMODOENSIS, THE LARGEST LIZARD IN THE WORLD

inches, but when the tape was applied it proved to be only twelve feet four inches long (Fig. 15). The largest specimen now in captivity is probably the thirteen-foot monster at Jacksonville. Individuals over ten feet long are now rare. As they are constantly hunted for their hides, few live to an old age.

While thirty-foot crocodiles have often been reported, none has as yet been actually brought to any museum. The skull of what is probably the world's largest specimen has been for nearly one hundred years in Boston and is now in the Museum of Comparative Zoölogy in Cambridge. About 1825, Mr. George R. Russell (born 1800), a merchant of Boston, spent some years in the Philippines. While there a Frenchman and he killed a gigantic crocodile which had for years taken a fearful toll of human lives, since it lived near a much-used ford in a stream near Lake Taal in Luzon. At length, after much shooting, the beast was killed and Mr. Russell brought home the giant skull (Fig. 16). This great crocodile was twenty-nine feet long and no less than eleven feet around the body behind the fore limbs. A very exciting account of its history during its life time and of the finally successful efforts to kill it with antiquated arms was written by Mr. Russell's French companion, Paul de la Gironière. A translation of his narrative entitled, 'Twenty Years in the Philippine Islands,' was published by Harper Brothers, in 1854.

Major Moulton, Chief Secretary to the Government of Sarawak, writes that he has a reliable Bornean record for a crocodile twenty-three feet long, which is very large nowadays. Modern arms are too well distributed for many very old crocodiles to survive.

Bigness for some strange reason has a peculiar fascination for nearly every one, and every hunter seeks a record.

The smallest types, however, are no less remarkable. The smallest adult snake is a Syrian Leptotyphlops, a tiny blind sand burrower, just about the size and shape of a steel knitting needle. The smallest lizard is but a couple of inches long and would probably not weigh five grams. It is found abundantly in the Sapo Mountains in eastern Panama. This lizard, *Lepidoblepharis sanctæ-martæ*, first made known from the Santa Marta Mountains of Colombia and rediscovered in the Chocoan forest of Darien, lives among the great fallen leaves of the rain-forest floor and is so lively and elusive that collecting a series is no easy task. In addition, its skin is as thin and delicate as wet tissue paper and its struggles, after being caught, usually leave it in sad condition. The smallest frog, *Phyllobates limbatus* (Fig. 17), comes from Cuba and was one of the author's most exciting finds in 1910, for the only known specimens had been taken sixty years earlier and the types (as the original specimens upon which species are described are called) had been for years so dried up as to be useless.

It is a far cry from this tiny Antillean frog to the great *Rana goliath* discovered but a few years ago in southern Cameroons and the Gaboon region of French West Africa. This giant (Fig. 18), which is as heavy as a good-sized terrier, is the largest known frog. It lives in deep sluggish forest streams and is only occasionally caught by the negroes in their fishing operations when the streams are low after long dry spells. The negroes eat them, as they do most things, and consider their thigh bones priceless for purposes of divination, so that few individuals ever get saved and but few museums have them.

While every one who may, does enjoy terrapin and green turtle and eats frogs to some extent, primitive people with more catholic tastes, or with less inherited prejudice,

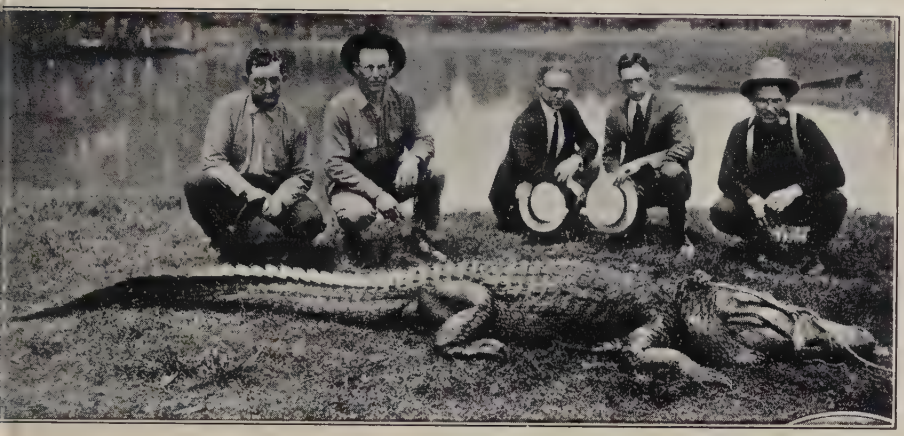


FIG. 15. 'AN EIGHTEEN-FOOT ALLIGATOR' PUBLISHED IN A SUNDAY SUPPLEMENT

It measured just twelve feet and four inches when actually measured at Bell City, Louisiana

FIG. 16. THE SKULL OF THE GIANT CROCODILE KILLED BY MR. RUSSELL AT JALA JALA, IN THE PHILIPPINES, NEARLY A HUNDRED YEARS AGO

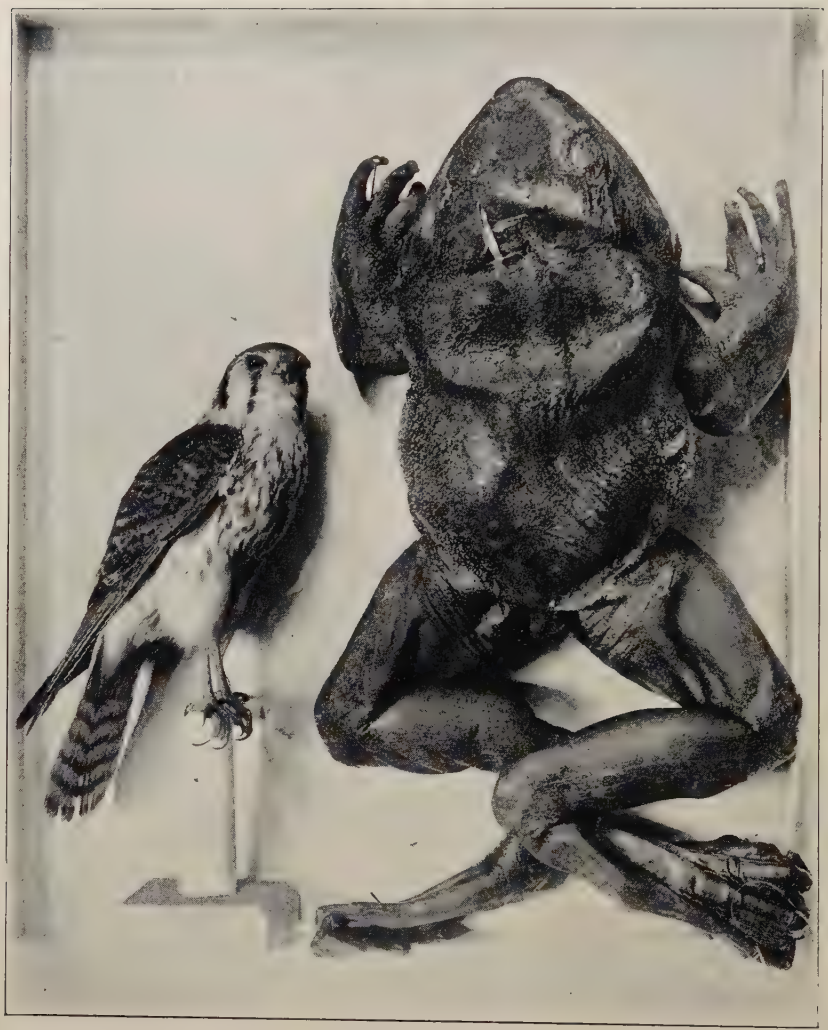


FIG. 17. PHYLLOBATES LIMBATUS FROM CUBA, ONE OF THE SMALLEST FROGS IN THE WORLD (*life size*)

FIG. 18. RANA GOLIATH FROM WEST AFRICA

This is the largest species of frog and probably the largest individual on record. It was shot with an arrow (see wound in head) by a negro near Efulan in Southern Cameroons.

eat many more forms. The Australians and the African bushmen eat most snakes and lizards. The Seminoles in Florida and many other peoples eat small alligators and crocodiles, and Indians generally throughout the American tropics eat large snakes, iguanas (*Frontispiece*), lizards, and turtles, whenever they can be had.

The large green iguanas (*Frontispiece*), so common in Central America, are brought to market in great numbers, the gravid females being especially esteemed. The meat of these iguanas, and of the various West Indian species now hunted to extinction by man, is white and delicate in the highest degree. They are caught with nooses on a long bamboo, or by chasing them into trees with dogs and they are then shaken from the branches as well as shot. In the markets they are harshly treated, being piled up like kindling wood, their strong flail-like tail chopped off, lips closed with a bit of bark fiber or with a long thorn, and their feet tied over their backs by their own sinews. The toe-nails, when twisted loose and pulled out, draw with them a strong tendinous cord, and thus a toe of each foot is tied to its fellow of the opposite side.

Green turtles have been so persistently hunted for the London and New York markets that the turtling schooners from Key West, Jamaica, and Grand Cayman scour the remotest islets and shoals of the Caribbean. The animals are caught in various ways; some are turned on the beaches when they come up to lay their eggs during the full moon of May, a few are harpooned, but this may injure them badly. Most of them are taken with a bullen, a heavy metal ring with a deep net to the end of which a long rope is tied. When the turtle is seen feeding on algæ or resting on the bottom in considerable depth of the clear still water, the bullen is dropped over him. The ring settles quickly,

and the turtle, rising instinctively when surprised, gets entangled in the net and may thus be hauled to the surface. One of the sights of such towns as Kingston, Jamaica, or Key West, is the turtle crawl, a great pen of upright logs in about eight feet of water. Here the turtles are held awaiting shipment and soon become very tame and feed voraciously on Salicornia or similar succulent herbage.

Even rarer now than the green turtle is the hawksbill, yielding horny plates overlying the bony skeleton which, after being removed, soaked in hot water, scraped, and pressed under heavy weights, become the blocks of tortoise shell from which many useful articles are carved. The loggerhead turtle (Fig. 20), somewhat similar in appearance to the green turtle, is still common, since it is less well flavored and supplies most of the turtle eggs (Fig. 21) sold in our Southern seaboard cities and in the West Indies.

The giant tortoises of the Galapagos are nearly extinct. They were formerly caught by the whalers and carried alive for months, then butchered. The water in their bladders was also regularly used as was their flesh. The Galapagos Isles, belonging to the Republic of Ecuador, once supported not fewer than eight species of giant tortoises, and according to some authors rather more. That these are now all but completely extirpated is hardly surprising when we consider that Baur, a careful student of tortoises, after visiting the islands and studying the literature, came to the conclusion that probably ten million of the creatures had been sacrificed not only to the visiting ships in search of fresh meat, but to the needs for oil of the more or less transitory colonies which had from time to time been established on the islands. Large areas thickly strewn with bleaching shells and bones persisted to within a few years, a mute record of this fearfully wasteful havoc.

Giant tortoises [1] not much different from these island forms existed in North America, notably in Florida and also in Cuba, down to very recent geological times. Nor were these the only allies, for there are giant tortoises still on South Aldabra in the Indian Ocean, and most of the tropical isles of that sea supported them until a few years ago. Their extinction was due to the same causes which wiped out the dodo, the solitaire, and other curious creatures which served the gluttony of the early voyagers.

As yet only the diamond-back terrapins [2] of our Southern estuaries are raised commercially, and unless some protection is given the sea turtles by international agreement they will inevitably disappear. Many species of fresh-water turtles are just as good to eat as the diamond-back terrapin, notably the soft-shelled turtles so-called, and many other fresh-water species. Snapping turtles (Chelydra) are especial favorites in the Philadelphia market and are being rapidly reduced in numbers in southern New Jersey, Pennsylvania, and Maryland. It is altogether probable that any or all of the North American species could be readily raised for commercial purposes on a large scale. It is true, nevertheless, that their use in North America is purely as a luxury. Not so in Brazil, where annually great crowds of whites and Indians camp on the sandbanks in the Amazon and the other large rivers. Here at the season of low water great hordes of water turtles repair to lay their eggs which for generations have been gathered and tried out for oil. These turtles serve a

[1] Also called giant land turtles, although in common usage the word 'tortoise' usually refers to a terrestrial species, but this is not obligatory. 'Tortoise shell' is taken from a marine species.

[2] Several other American river and pond turtles are commonly called 'terrapins.' The true 'diamond-backs' are the several species of the genus Malacoclemys.

vital need to the population of the State of Amazonas, but so wasteful has been the method of harvesting and so few the eggs 'left for seed' that already the seemingly inexhaustible supply is far smaller than when the life of these egging camps was so fascinatingly described by Bates and Agassiz.

CHAPTER III

CONCERNING POISONS AND POISONOUS SNAKES

It is, of course, the venomous snakes which really play the most important part in the relation of reptiles to man and the higher animals. Aside from the sea snakes, which are simply water cobras and all highly venomous, there are in round numbers 250 species which have the poison apparatus well developed. Of this number at least 75 may be disregarded because of their rarity or their very small size, leaving but perhaps 150 or 175 out of 2300 species, or about seven and a half per cent of the total number of snakes known.

In North America our rattlesnakes, or copperheads, water moccasins, and coral snakes cause but few deaths in any one year, though, since motor campers abound over the whole country, there are more casualties than there used to be. In Europe, where reaping, binding, and gleaning are more often handwork than in America, there are a good many viper bites, but few fatalities. The African poisonous snakes, while abundant in species and some of them very dangerous, seem not to cause great loss of life, but from wide areas there are no statistics. Still there are localities where this is not the case. India and southern Brazil, with Australia to a less degree, are the regions where most fatalities occur.

No accurate statistics are available from northern Brazil. Therefore, using as a basis the statistics of the State of São Paulo in southern Brazil, where there is a very large rural agricultural population, Dr. Vital Brazil concluded that in all Brazil, before anti-venomous serum was

largely introduced, there were probably about 19,200 snake bites a year and some 4800 deaths. He figured that, leaving out of account farm animals which also suffer largely, the loss in agricultural time on account of men incapacitated was nine or ten million dollars' worth per year. While there are still probably two thousand persons bitten every year in the State of São Paulo alone, the number of deaths from snake bite has been reduced from a couple of hundred each year to an average of from three to five for every year since 1919. This is due entirely to the wonderful work of the State's Biological Institute at Butantan (Fig. 26), near the city of São Paulo. Here horses are immunized by the administration of small and then larger injections of venom until their tolerance becomes finally very great; the blood is then drawn off, the serum removed, sterilized, concentrated, and put in tiny glass ampules which are sent far and wide. The recipients are requested to return the favor they receive by sending recently caught snakes to the serpentarium of the Institute so that new horses may be immunized and the good work increased.

Dr. Fayrer, a British physician in India, concluded some years ago, after many years of observation, that probably one native in 10,000 dies from snake bite each year in India, where vital statistics are most uncertain. Allowing, therefore, for a population of 290 millions, we have about 29,000 deaths in a year, which is probably somewhat beyond but not far from the truth. A combination of circumstances accounts in some degree for this fearful toll. On the arid plains region the sun beats down fiercely by day, but during January, February, and March, the drop in temperature at sundown is very considerable. The snakes know that the warmest place then is the deep dust of the sun-baked roads which long retain their heat; more-

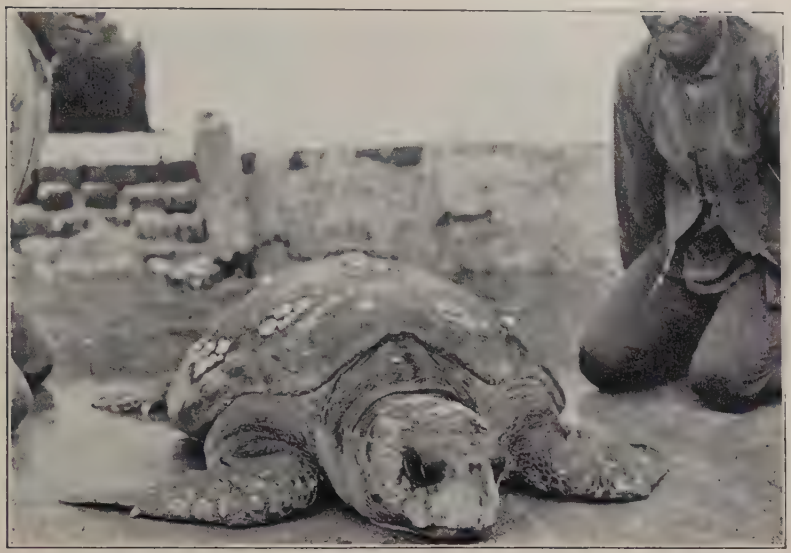


FIG. 20. A TYPICAL SEA TURTLE, THE LOGGERHEAD (CARETTA CARETTA)

Note its obvious helplessness on land. The powerful jaws crush corals and calcareous algæ as well as molluscs, and old individuals may often be seen eating the fearfully stinging Physalia or Portuguese Man-of-War. They close their eyes as they bite into them. East coast of Florida.

FIG. 21. THE EGGS FROM THE SEA TURTLE FIGURED ABOVE

These eggs are laid in the sand in a deep hole. Felt by prodding with an iron rod, they are easily found and much sought for food. This lot shows two batches, one ready for laying, the other less developed. Turtles usually haul out for laying on the Florida beaches on the full moon of May.

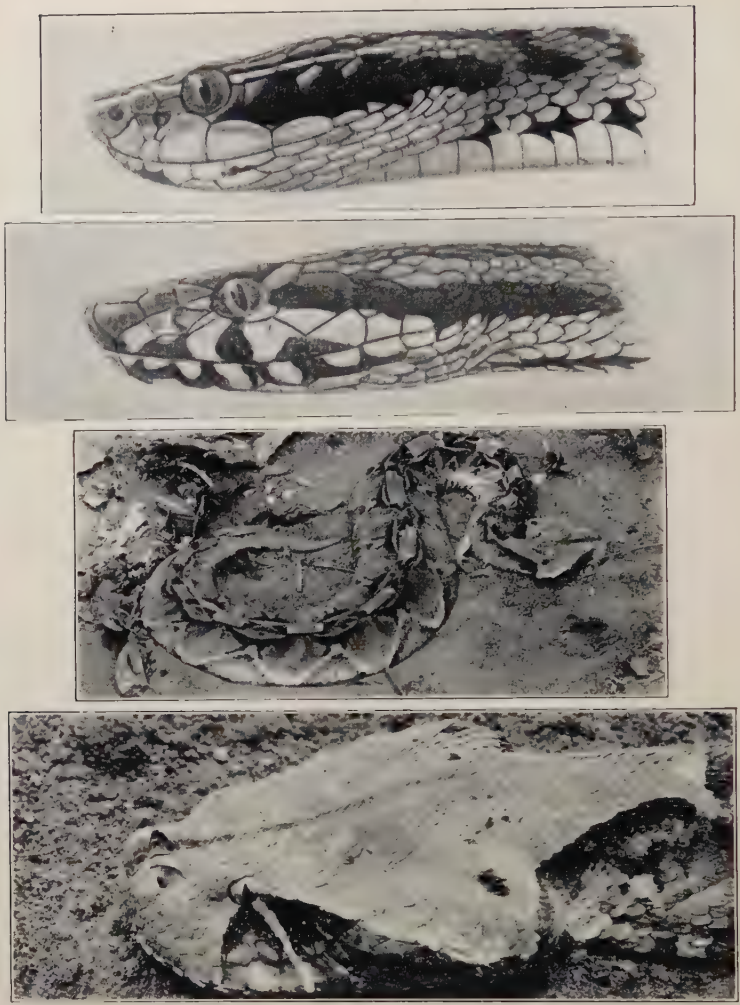


FIG. 22. A CHINESE VIPER (AGKISTRODON BLOMHOFFII) WITH A NORMAL FACIAL PIT

FIG. 23. THE TIBETAN A. STRAUCHII WITH A PIT OPEN TO THE ORBITAL MARGIN

FIG. 24. BITIS GABONICA, A GIANT FOREST VIPER FROM WEST AFRICA

Its rich, somber colors blend well with the dead leaves of the forest floor.

FIG. 25. HEAD OF THE SAME VIPER

over, the peculiarly itinerant Indian population knows that it is far cooler walking by night than by day. Almost no one wears shoes, and the result is many cases of snake bite. Only a few of the snakes are ever identified, so that, even near centers where the anti-venine is available, the chance of a cure is reduced, for the anti-venine for cobra bite differs from that to be used for Russell's Viper. The latter and the several species of kraits, do most of the killing and are far more feared by most Hindus than are the cobras. They lie more quietly, are less active, and less inclined to get out of the way.

The cobra is held sacred in many localities and therefore comes to lead an almost semi-domesticated existence. The fact that a pair may come to live under the floor of the village temple is a good rather than an evil omen. A dish of water or milk is put near their lair each day, and no one disturbs them, for they help to kill the rats which are a real pest. Of course, accidents happen and some who step carelessly get bitten and die. I was once asked to come and kill a large cobra that lived in a rat-hole near the much-used path leading to a village near Lucknow in Oudh. This cobra was really disliked, for he had bitten several people who perforce passed him. No one in the village would disturb him; on the other hand, no one cared if a stranger's future prospects were clouded by the murder. The cobra is said to be sacred since it spread its hood to shade the face of a napping divinity. The markings on the hood are claimed to prove this fact, since beyond doubt they represent the persisting finger-prints of the blessing bestowed when the god awoke.

That the members of the family Elapidæ [1] are very ancient geologically is shown by the fact that most of the

[1] Poisonous snakes with anterior short immovable fangs.

Australian and Papuan species belong to this group, for this area has long been isolated and has received but few geologically recent immigrants of advanced type. Nearly all of the Australian snakes are poisonous. Many are rare and small, but the death adder, the Australian black snake, the tiger snake, and a few others are greatly feared. Throughout the tropics of Asia and Africa, the cobras, the kraits,[1] and the mambas or tree cobras are the most widespread and prominent Elapine types, as are the thirty-odd species of coral snakes, the only representatives of this stock in tropical America. One species, *Elaps fulvius*, ranges throughout the southeastern United States to North Carolina.

The great bulk of the American venomous species, however, are pit vipers, forms having a small cavity in the loreal region just before the eye (Fig. 22). What the function of this cavity may be is entirely unknown. It is heavily innervated and seems to be an outpocketing of the anterior corner of the orbit with which in rare cases it may be openly connected, as in a Tibetan example (Fig. 23) described by the author some years ago. There are no pitless vipers in America. All the rattlesnakes, the moccasins, and the copperheads, closely related forms, and the many tropical allies of the bushmaster, are of this pitted group. In the Old World there are a few pit vipers in southeastern Asia, but the greater part by far are pitless types, of which the great vipers of Africa (Figs. 24 and 25) and Russell's Viper in India are the most striking and dangerous.

The sea snakes are all simply marine Elapines provided with a flat rudder-like tail, and nostrils on top of the head

[1] The Indian name given to the members of the genus Bungarus, usually small and brilliantly banded allies of the cobra.

closing with valves (Fig. 50). They are found in all warm waters except the Atlantic, and they swarm in the Red Sea, the Persian Gulf, and the Java Sea and Gulf of Siam. One species (*Pelamydrus platurus* [Schn.]) is very common in the Bay of Panama.

Cobras (Naia) in India and the several species of fer-de-lance (Bothrops) in Brazil are probably the most abundant of poisonous species. During 1902 the Brazilian Serum Therapeutic Institute of Butantan near São Paulo received no fewer than 7293 of these dangerous creatures in response to an appeal to send them in for use in immunizing horses!

A noteworthy feature of the poisons is their varying activity in closely related species that have different feeding habits. While it is true that the great majority of venoms are as yet uncritically studied, we know, especially from the careful researches of Amaral, the highest toxic valence yet discovered is that of the viper living on Ilha de Queimada Grande off São Paulo State, a steep hilly island about forty miles off the coast of southern Brazil. Why should this be the case, for *Bothrops insularis* is not structurally so very unlike its mainland allies? The reason is beyond doubt to be found in its habits. No food is available on this rocky island suitable for a viper except the common neotropical sparrows of the genus Brachyspiza. Now, to secure enough of the shrewd, active little birds, the poison must be so strong that no escape by flight is possible after the prey is struck, for most vipers do not hold fast to their victim as do many short-fanged snakes, but strike and withdraw at once.

A common laboratory standard of toxicity is the minimal lethal dose per pigeon. The venom of *Bothrops insularis* has a toxicity 4/1000 of a milligram intraven-

ously and 40/1000 of a milligram intramuscularly, a very astoundingly high toxicity. The true fer-de-lance (*Bothrops atrox*), which feeds wholly on rodents in a wild state, has a lower toxicity, 10/1000 of a milligram intravenously and 500/1000 of a milligram intramuscularly. Another allied viper, *Bothrops jararaca*, which feeds not only on rodents but often also on frogs, has a still lessened toxicity of 20/1000 of a milligram intravenously and 700/1000 of a milligram intramuscularly; thus showing that there is a very definite relation in these cases certainly, and in some others which could be added, between the potency of the poison and the speed with which it must work to be most useful to its producer. Less active poison suffices for less agile prey.

Since, however, the poison varies in every species and there are many details of life-history which also vary from one species to another, and since many species are still very incompletely known, it may not be possible as yet to interpret all the observations which are made, but there are certain general conclusions which can now be advanced. Thus the poison of the sea snakes, while dangerous to man, is almost instantaneously fatal to fish. The poison of Elaps, the coral snakes, likewise slowly but surely active upon mammals, is very rapidly active upon other reptiles, for the species feed largely upon lizards or snakes; and, as we have seen, the unique island Bothrops has a poison which is instantaneously active upon birds.

The question often arises how poisonous snakes may be told from harmless ones. The answer is that they cannot be. However, some vipers surely do look very poisonous. Who would ever say that the fearful Gaboon viper (Fig. 25) of the West African forest looked harmless? Surely no one, for it is the most awe-inspiring of all serpents. Its

gorgeous colors blend into the somber forest floor and its bulk makes possible the sudden launching of its great broad head, broad in order to make room for the giant poison sacs. Still another vicious viper (Causus) in the same region looks quite harmless, and, instead of having great bulging poison sacs, it has long ones like the Elapine Doliophis, extending far into the body cavity. Many of the Elapine poisonous snakes appear wholly harmless to the observer, and only one, Acanthophis, really *looks* venomous. It is found in Australia, New Guinea, and the Island of Ceram and it looks like a true viper. For this, the dreaded death adder (*Acanthophis antarcticus*) is the one Elapid with a triangular head. One of similar appearance has caused the natives to name a common Javanese viper (*Agkistrodon rhodostoma*), 'Ular daun depok Kapala,' 'the snake with a head like a leaf-shaped battle-axe.' Conversely some harmless snakes are very viper-like in appearance.

CHAPTER IV

CONTROL OF POISONOUS SNAKES

Various methods of reducing the numbers of poisonous snakes have been tried. The offer of bounties on vipers in France resulted in wholesale importation of vipers from distant districts. The same offer in India simply ended in the extensive garnering of eggs which have many natural enemies and to their being hatched in regular hotbeds for the benefit of the bounty market; so this was given up.

All snakes have natural enemies, but these do not seem ever to multiply beyond the ordinary number predicated by the natural balance of Nature. The mongoose (Fig. 27), which feeds on snakes, is widespread in the Orient, but is nowhere abundant until planted in new soil. The mongoose attacks the snake by waiting its chance and then catching its head in its mouth in such a way as to pin the jaws closed and to penetrate the brain with its needle-like canine teeth. Then it holds fast while the snake coils and thrashes. It is not immune to poison, it chews no vegetable antidote if bitten. It is simply too keen and quick to be harmed and it seems to possess a fiendish joy of battle. It may or may not eat its victim. Brought to the West Indies, first to Martinique and St. Lucia, where the fer-de-lance (*Bothrops atrox*) occurs, a mongoose, for there are many species, did reduce their numbers, but, carried to most of the other islands and also to Hawaii to rid the cane-fields of rats, it became excessively abundant, but the rats escaped by becoming arboreal and nocturnal — the mongoose is neither. And then, when it had exterminated the various ground-nesting birds or reduced them till they

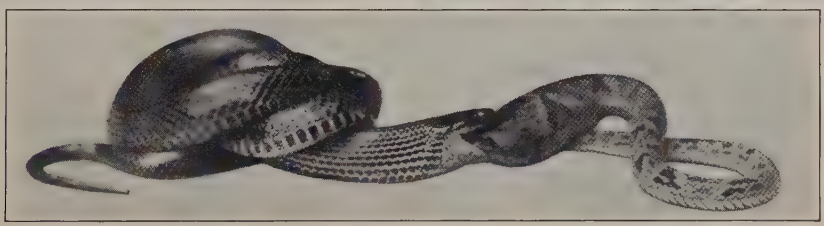


FIG. 26. THE SERUM THERAPEUTIC INSTITUTE AT BUTANTAN WHERE ANTIVENINES ARE PREPARED

In the foreground the serpentaries where living snakes used to immunize the horses are kept.

FIG. 27. A MONGOOSE KILLING A COBRA

FIG. 28. CONEPATUS CHILENSIS, 'CANGAMBÁ' (SNAKE-EATER)

FIG. 29. CLELIA CLŒLIA, THE MUSURANA, EATING A DANGEROUS VIPER, BOTHROPS NEUWEIDII

FIG. 30. SPECIMENS SHOWING HEAVY BUT SHORT POISON FANG OF INDIAN COBRA
Note the bristle passed through the fang

FIGS. 31 AND 32. A VIPER'S SKULL WITH FANG AT REST AND RAISED FOR STRIKING; TO SHOW THE INTERACTION OF THE BONES

FIG. 33. HEAD OF A FLORIDA RATTLESNAKE DISSECTED BY DR. JEFFRIES WYMAN
Showing the poison sac and the sigmoid duct leading to the base of the fang. A bristle has been thrust into the aperture through which the poison is poured into the tooth.

had become too rare to hunt for, the mongoose invaded the hen-yards, so that now a bounty is being considered on the mongoose. The disastrous results of the introduction of foreign elements into any fauna are too well known to need further discussion here.

Serpents have other enemies which it is believed would be well worth encouraging artificially in the regions where they naturally occur. The European hedgehog has venomous blood and shows a high natural immunity to snake poison. It feeds largely on the European vipers where they occur. In northern and central Brazil, a skunk, *Conepatus chilensis* (Fig. 28), is resistant to fer-de-lance and rattlesnake venom, and its blood has strong anti-toxic qualities, though it is not in itself venomous. Thus an animal ordinarily to be killed by injecting into it serum from hedgehog blood is rendered considerably resistant, experimentally, by the serum from the blood of this peculiar skunk.

Both species feed on snakes, but their blood has for some unknown reason reacted in an entirely different physiological manner. Nevertheless, both types are immune themselves to the poisons of the snakes upon which they regularly feed. There are now clearings in Brazil where this skunk becomes abundant and has extirpated some of the smaller vipers. Curiously, the skunk of southern Brazil, *Conepatus suffocans*, is not ophiophagous and its blood shows none of those physiological peculiarities which seem to be connected directly with the habit of snake eating.

The great king cobra of Malaya feeds wholly upon snakes, but is himself far more dangerous than any he might eat. This is not the case with our king snake (*Lampropeltis getulus*) and its allies, nor with the musurana (Fig. 29) of

Brazil. These snakes, harmless and inoffensive when handled by man, perform a useful service in devouring poisonous snakes. Our king snakes, of the large genus Lampropeltis, will eat any snakes, useful or poisonous, but the musurana (*Clelia clœlia*) seems deliberately to pick out the genus Bothrops, perhaps because it is very common, and to this genus the fer-de-lance and several other equally dreaded species belong. Other snakes also are promiscuously cannibalistic.

Certain birds are active destroyers of reptiles, but few prey on other than the harmless species. Some of the large ground cuckoos, like the 'road-runner' of our West, eat lizards regularly, and in captivity and perhaps at large will kill and eat snakes. Our red-shouldered hawk seems to feed almost exclusively on snakes, at least in Florida. The curious cursorial hawk, the secretary bird of South Africa, eats any and all snakes, as do some of the great heavy-billed storks and ibises which kill their prey with blows of their powerful beaks.

CHAPTER V

THE FANG, ITS ORIGIN AND FUNCTION

In order to find, if possible, existing types which represent, as arrested stages of development, the various progressive modifications which finally culminated in the giant vipers with their mechanically elaborate apparatus for the injection of poison, it is necessary to examine the teeth of primitive snakes.

All primitive snakes have solid teeth, and likewise have another presumably primitive character, the presence of a keel-like hypapophysis on the ventral aspect of the centrum of each vertebra. The course of evolution to the higher poisonous types was probably something as follows — a history which is not easily recapitulated in simple terms. From the most primitive or simplest condition with teeth on all the dentiferous bones, those on the premaxillæ first are dropped, as seen in certain tropical allies (Polyodontophis) of our garter snakes. From this type, by many and usually inconsiderable modifications, the teeth become reduced in number and different in size until in the African Boodon, still with the vertebral hypapophyses, the anterior teeth in the upper jaw have become large and fang-like, although still solid and ungrooved. From some such type it may be assumed that the fang of the cobras and the coral snakes, the Elapine types, has been derived through the shortening of the upper jaw and the appearance of grooves on the anterior fang-like enlarged teeth. Within the Elapine series, varying stages show grooves deeper and deeper until by the overgrowing and meeting of the margins of these grooves the perforated fang of the coral snakes

and their allies is attained (Fig. 30). Indeed, in the genus Elaps,[1] to which our coral snake belongs, all the maxillary teeth except the fang have disappeared, and the little teeth on palate and mandible are much reduced in number. This is the culmination of the series represented by the families Elapidæ and Hydrophidæ (cobras and cobra allies and sea snakes), the Proteroglypha (with anterior fangs), to which perhaps one half or more of the venomous species belong.

From the primitive isodont or the aglyphous or fangless types, where no teeth are especially enlarged, another stem has branched off. In this, the posterior, not the anterior, teeth are increased in size until finally the other solid teeth are somewhat reduced not only in size but in number, as in Xenodon, or still more aborted until but two or three little teeth remain and large and deeply grooved fangs stand behind them. Such a form is the rare and diminutive African genus called Miodon, and from such a type by further reduction the transition to a single large perforated fang is easily postulated. In this opisthoglyph (with hinder fangs) series the vertebral hypapophyses have been lost and a still greater advance has been made beyond the Elapine equipment. For, finally, the maxillary bone has become progressively shortened until it is a mere hollowed-out block of bony tissue with a single, great, strongly set fang (Figs. 31 and 32). This may be very long, for, by a simple mechanism connected with the opening of the mouth, jawbone and fang may be rotated to an angle of 45° and so a vastly longer and more serviceable tooth may be accommodated. It may lie along the roof of the mouth when not in use and be brought forward for the strike.

[1] I retain the name Elaps because it is so familiar. It is more correct to use Micrurus, an earlier term.

This motion comes with the contraction of the digastric muscle, which runs parallel to the quadrate bone from the squamosal to the posterior end of the mandible, and thus throws down the lower jaw, while at the same time the pterygoid bone, lying along the roof of the mouth, is thrown forward, as the quadrate swings with the opening jaw. This movement is passed on to the ectopterygoid and so to the maxilla, which in turn is rotated and the fang snaps forward into place, lying until disclosed in an elastic covering of folded mucous membrane. This is the viperine or solenoglyphous type of poison apparatus (Fig. 33), different in origin and in every other way from the Elapine type. Indeed, as will be seen (p. 34), the poison in general is wholly dissimilar in the two groups, an added proof of dissimilar ancestral histories.

Such in brief is the outline of the evolution of venomous snakes proposed by G. A. Boulenger, the great Belgian herpetologist, long at the British Museum. It is somewhat dissimilar to a very much less plausible theory advanced by Madame Physalix, a distinguished French physiologist, who, with less knowledge of systematic zoölogy, proposed a scheme whereby the viperine types, with movable fangs, are derived directly from the poisonous snakes with short fixed fangs.

Vipers strike by stabbing forward, often with terrific speed and force, and the fangs are driven deep and then at once withdrawn, while the snake waits for the death of its victim. This results in the frequent loss of fangs, so that spare teeth, graded from full size to tiny tooth germs, lie in a fold of tissue behind the fang, so that if a fang is lost one of these teeth moves forward and in a short time becomes firmly cemented into the place of the lost tooth.

The Elapidæ with their short immobile fangs grasp the

prey and do not stab, but bite and chew for several seconds, to allow their shorter, hence less effective, hypodermic needle to have its full effect.

One common African genus of snakes, Dasypeltis, feeds largely on birds' eggs and in these the inferior processes of the vertebræ penetrate the gullet and saw through the eggshell as it passes by on its way from mouth to stomach.

CHAPTER VI

THE POISON

The poison is derived from modified glands which lie above the lip margin and are homologous with the parotid salivary glands of the higher animals. The saliva of even the most harmless snakes is slightly toxic, and it was beyond reasonable doubt this fact which allowed selection to play a predominant part in the elaboration of an apparatus for the injection of saliva and the transformation of the saliva into the two types of poison characteristic of the two venomous groups. The gland opens into a tubular duct which terminates in a fringed membranous mouth. This duct, passing the fang and turning upon itself, is closely applied to an opening on the anterior face of the upper end of the fang. By the compression of a ligament the poison is forced out through the duct and tooth which has another slit-like opening on the anterior face of its very tip (Fig. 33).

The poison itself is a thick, viscous, usually yellowish, clear, or very slightly cloudy liquid which upon exposure to the air yields from twenty-five to fifty per cent of its weight in brilliant yellow crystals. These, when kept in a sealed container, retain their toxicity for years. They are always soluble in a weak salt solution (say about one per cent) and some are soluble in ordinary distilled water.

The poison may be obtained by grasping the snake by the neck (Fig. 34), placing a watch crystal or stender dish in its mouth, and then manipulating the gland with the fingers. Lamb in India declares that more poison is given off during a natural bite than can be obtained

by manipulation. The amount of dried poison obtainable varies from less than ten milligrams in the case of some of the sea snakes to no less than four hundred milligrams in the case of the Brazilian bushmaster, while the other venomous species form a more or less intermediate series within these limits.

The toxic activity varies, more or less, with the species, as previously stated (p. 23), and has at least some correlation with the character of the prey; also the amount of poison which experiment has shown to be commonly ejected by an average adult snake determines to some degree the amount of the specific anti-venine which is to be injected to effect a cure.

Physalix, the French investigator, has found that electricity and radium rapidly destroy the toxic power of snake poison, as does also heat; various venoms are destroyed at from 65° to 120° Centigrade, varying with the amount and resistance of the albuminoid components and other proteins. Snake venom in most cases may be swallowed with impunity, and digestion destroys most of these poisons, but the Old World vipers, the cobra, and the dreaded black snake of Australia (*Pseudechis porphyriacus*) secrete poison which is resistant to gastric juice.

The biochemical results obtained from analyses of poisons by different observers are extremely complicated and by no means always mutually confirmatory. In regard to this topic, the curious reader may be referred to the published works of Physalix, Noguchi, Loeb, Flexner, Lamb, Brazil, and especially Amaral.

The physiological action of the poison is naturally of much interest, for this explains just what happens when one is bitten.

The poison may be neurotoxic, working primarily upon

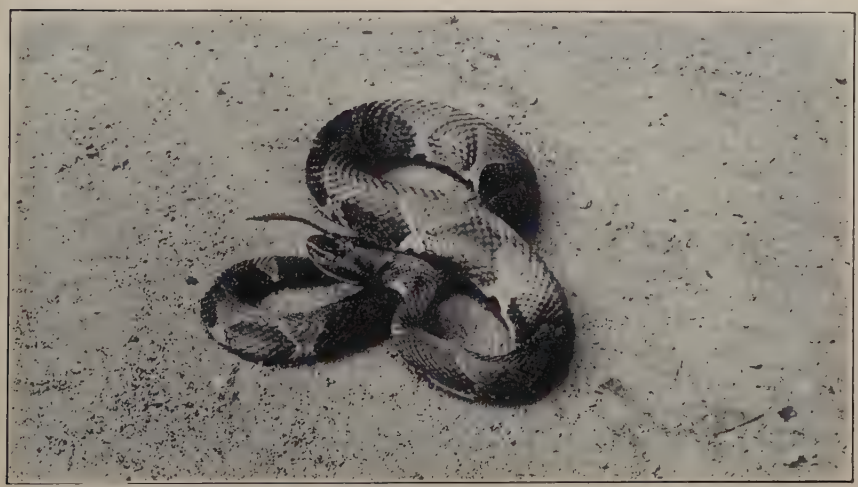
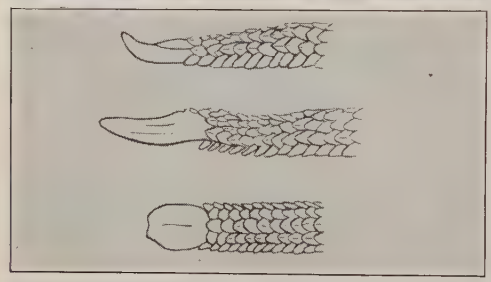


FIG. 34. HOW SNAKES ARE MANIPULATED AT THE SERUM THERAPEUTIC INSTITUTE AT BUTANTAN, SÃO PAULO, BRAZIL
The poison is being squeezed into the small glass dish.

FIG. 35. A COPPERHEAD FROM BLUE HILL, MASSACHUSETTS



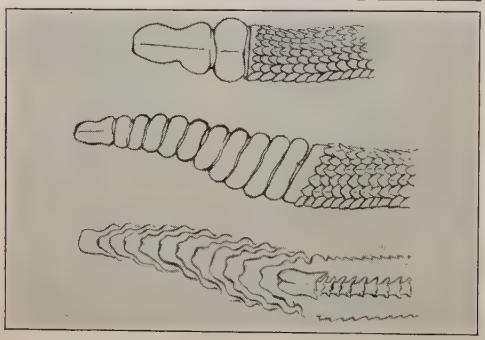


FIG. 36. THE JAWS AND SKULL OF A PYTHON

Note the lower jaws separated and the tooth-bearing bones of the upper jaw so hung to the brain-case by ligaments that all dentiferous bones can be moved and help work the prey into the gullet.

FIG. 37. THE JAWS AND SKULL OF AN IGUANA

Typical of the condition seen in lizards and to be compared with the less compact ophidian skull.

FIG. 38. TIPS OF TAILS OF SNAKES

Upper two, non-rattling vipers; lower four showing rattle during growth, lowest in cross section.

FIG. 39. THE RATTLE OF THE RATTLESNAKE IN LIFE

the nervous tissues of the body; or it may be hæmolytic, breaking down the red blood cells with accompanying rapid gangrene, while also the arterial and venous walls are broken down, causing extensive extravasation or oozing of blood. In general the venom of the Elapid types is much more neurotoxic than is that of the vipers, but there is an exception in the case of the South American rattlesnake, which, unlike our Northern species, has a strongly neurotoxic poison, one which not only inhibits respiration, but attacks selectively also the optic nerves so as to produce blindness. It is very remarkable that two rattlesnakes so similar in every appearance as *Crotalus terrificus* of Brazil and *Crotalus adamanteus* of Florida should have such entirely dissimilar venoms. The venom of many of the Old World Elapids, and of the Indian and Australian forms, causes a paralysis of the phrenic nerve which controls the diaphragm.

In the poison of most of the vipers there is some of the neurotoxic element as well as far more of the cytolytic and hemorrhagic. Very many other elements have been isolated which may or may not be common to both types, but these suffice to show their essential differences.[1]

In the act of biting, the poison is, of course, usually introduced into the subcutaneous tissues or into the muscles. Penetration to the blood system is then rapid, since the capillaries may not be the only channels, but the

[1] This list comprises the components which up to the present time have been more or less definitely isolated in snake venom and which by being present in varying quantity give each venom its specific peculiarity: A fibrin, an anti-fibrin, and a proteolytic ferment; cytolysins capable of acting on red cells, leucocytes, endothelial cells in the blood vessels, nerve cells as well as the cells of other tissues; other cytolysins of the nature of amboceptors, which are probably distinct for each sort of cell; agglutinins for the red blood cells; an anti-bactericidal substance; neurotoxins, varying with the species, in regard to selective nervous affinity; a substance which reinforces the cardiac tonus.

very tissues themselves are pervaded in some species. As Amaral says, infiltration is rapid because of this peculiar affinity which some of the components have for the tissues themselves. As will be seen later, in the discussion of the spitting snakes, absorption is rapid through the conjunctiva of the eye, but not through the mucous membrane, if it is unbroken.

The descriptions of various types of snake bites vary clinically, as the following cases cited from Amaral serve to indicate. In the case of the cobra (Fig. 43), the bite is followed by a severe local burning sensation, œdema of the part bitten, prostration, and somnolence, extreme salivation, nausea and vomiting, cold sweat, and a rapid pulse changing to a weaker and slower one with passing time. Aphasia ensues, then progressive paralysis, and the untreated patient dies from respiratory paralysis, sometimes in twenty or thirty minutes, but usually far more slowly. But if the dose of poison be less than the minimal lethal dose, recovery is rapid and the symptoms fast disappear.

In case of poisoning by the related kraits of the genus Bungarus, there is no local reaction and the patient remains subconscious until death takes place. Bungarus poisoning may be very slow in its action, delayed death not ensuing sometimes for several days. Cases of poisoning by our American coral snakes are rare, but probably over seventy per cent of them are fatal. The reaction is somewhat similar to that of Bungarus poisoning except that there is local pain. In all of these snakes the neurotoxic component of the poison is obviously preponderant in its effect.

The exact reverse is seen in the cases of bite by Russell's Viper. Here there is instantaneous local reaction with hemorrhages; if the patient resists immediate death, the local œdema spreads rapidly, hæmaturia and albuminuria occur, and finally anæmia and intense emaciation, causing death.

Even more fearfully impressive are the results of the bite of the bushmaster and the fer-de-lance and their allies. Here one meets with immediate œdema, terrible pains, and hemorrhage by subepidermic infiltration. Later, because of the destructive action of the poison on the tissues, especially upon the red blood cells and upon blood coagulation, general symptoms appear. These consist of parched throat with thirst, and hemorrhage through mucous membranes and in the intestinal tract, indeed sometimes through the skin, especially about the eyes and the mouth. When death does not occur promptly, gangrene appears with progressive necrosis and mutilation.

These examples of the different specific actions could be multiplied many times, showing that each poison causes its own peculiar reaction according to the proportions of the different active principles contained. Still there are obvious similarities seen in the venoms of the related groups of species.

While in general it is wisest to use an anti-venine made from the same species as the one causing the bite under treatment, nevertheless the anti-venines have some para-specific action. Thus, since there are generally some neuro-toxic or hæmolytic elements in all snake poisons which are still predominantly one or the other, just so any anti-venine may help a 'borderland' case where death or recovery is at a close balance. Recovery might be determined by the elimination of one factor by the administration of an anti-venine which was not specific. In practice this often happens, and it is wise to use any available anti-venine in treatment if the specific serum is not at hand. Death is the result of the sum of the activities of the several toxic factors and the chance to eliminate any one should not be neglected.

CHAPTER VII

EFFECTS OF FEEDING HABITS ON DENTITION

The discussion of ophidian dentition is illuminating, for it shows how feeding habits that are essentially similar in a large group may bring about essentially similar dentitions. All snakes' teeth are fundamentally alike: slender, single, thorn-like teeth (Fig. 36), which, with the exception of the grooved or tubular fangs, differ one from another only in degree, not kind; that is, they may be longer or shorter, stouter or more slender, more or fewer in number. There is no such astonishing variety of dentition as may be seen, for instance, among mammals.

The lizards (Fig. 37), on the other hand, vary largely in feeding habits. They may be raptorial and may tear up animal prey, or they may be vegetable feeders, with many intermediate types. Lizards, therefore, have teeth which look like canines, as, for instance, in Liolepis; they may have anterior teeth modified for cutting and back teeth modified for grinding and canine-like teeth as well, as in several other genera of the Old World family Agamidæ. While no homology can be established between lizard teeth and mammalian teeth, still the parallelism shown in their forms is very instructive. The more generalized lizards, which bite and chew, vary far more in this respect than do the highly specialized snakes with their highly specialized method of feeding. For all snakes eat in the same manner, by pulling their flexible head over their prey, each of the four jaws catching hold by turn as they push forward one at a time. The only exceptions are the narrow-mouthed burrowing species of the families Typhlopidæ and

Leptotyphlopidæ, which may eat small insects or even caterpillar dung; and the slug feeders, such as Sibynomorphus in the New or Amblycephalus in the Old World, which, having no occasion to expand their jaws greatly, have lost the chin groove of elastic skin so essential to snakes that feed on prey of greater diameter than themselves. In general, then, snakes' manner of feeding is the same, whether a python swallows a hog (Fig. 40) or a slender tree snake a tiny lizard.

It is, therefore, fair to suppose that snakes derived from some lizard-like ancestor have gradually assumed secondarily the apparently very primitive and certainly very simple form of dentition seen, for instance, in the aglyphous or fangless types (Fig. 36), and that they have then proceeded to reëlaborate their own special contribution to the varieties of odontography by elongating certain teeth, developing a groove along one face of the tooth, and then, as the groove became deeper and deeper, finally approximating its lips until these fused and a tubular hypodermic needle was formed, ready to aid the introduction of the poison already developed much earlier in the phylogenetic history.

The first person to describe accurately the anatomy of the viperine fang was not, curiously enough, one of the widely recognized naturalists of his time, but Dr. Robert Knox, a Scotch surgeon long stationed in South Africa, who in 1826 published his now almost forgotten paper in a volume of a rare old series published in Edinburgh,[1] and thus first called the attention of the scientific world to the relation of the hollow fang to the poison sac, to the fang's growth, and to its being renewed in case of loss by the loose-lying and more rudimentary teeth.

[1] *Proceedings* of the Wernerian Natural History Society, vol. 5, for 1824–25, p. 411–21, pl. 10.

CHAPTER VIII

PROTECTIVE DEVICES OF SNAKES — ABNORMALITIES

Rattlesnakes. We have discussed the adaptation for securing food which is to be considered the preëminent specialization of snakes. Let us now consider some of the less remarkable, even if still somewhat spectacular, developments which the snakes have elaborated.

The rattle of the rattlesnake [1] is more or less familiar to every one. Those who have not seen or heard it have surely heard about it. It seems at first thought to be one of the most difficult of developments to understand and explain. However, when we consider the habit, which a vast number of different species of snakes have, of vibrating the tip of the tail when they are excited, together with the fact that the outer horny layer of the skin is shed at frequent intervals, it is not difficult to look back over what have very probably been the steps which led to the formation of the rattle. Many species of snakes, such, for instance, as the bushmaster and the copperhead, have a large horny spine at the end of the tail. It is only necessary to suppose that some ancestor of the rattlesnake in the distant past had such a spine, which perhaps swelled into a knob possessing a slight constriction about its circumference. Now, since the outer covering of this terminal scale, whatever its form, is shed just as are the coverings of all other scales, this constriction allowed the shed layer to be left hanging as a dry shell upon the new layer which pushed it off. This is indicated on the diagram (Fig. 38). The result is a string

[1] All members of the genera Crotalus, with small scales on the head, and Sistrurus, with large plates on the head, are called rattlesnakes.

FIG. 40. A PYTHON SKINNED AND OPENED TO SHOW AN ADULT WILD PIG JUST SWALLOWED

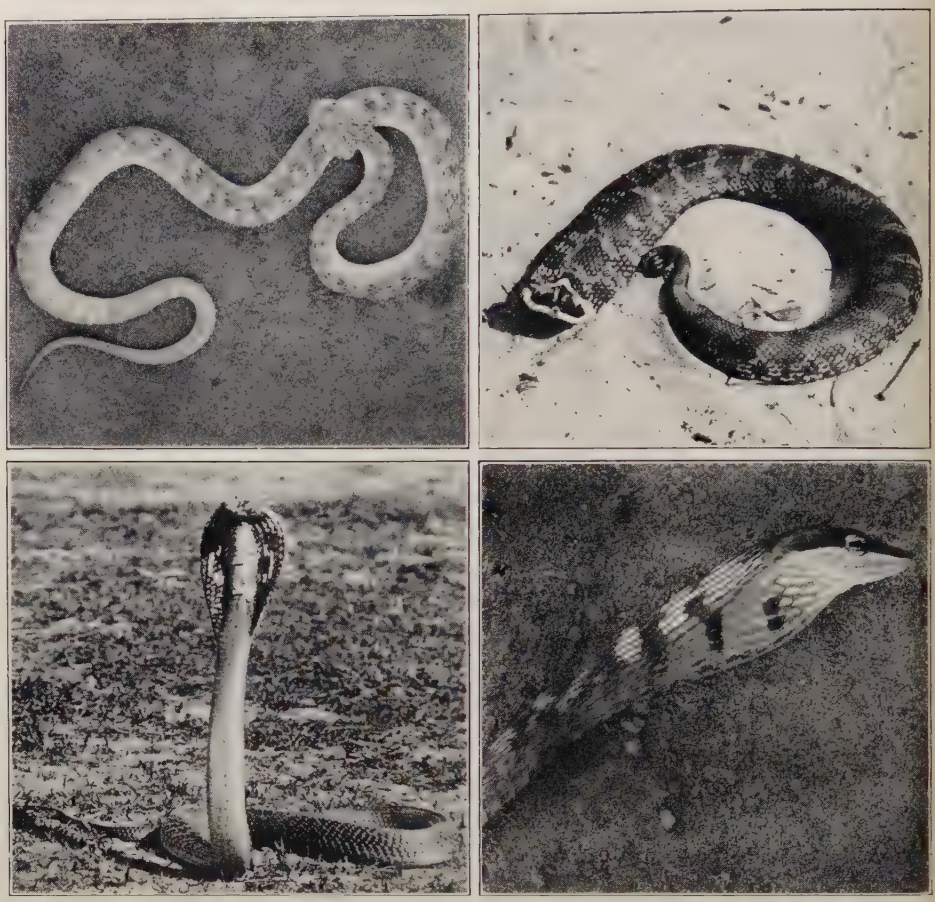


FIG. 41. ATHERIS, A GREEN TREE VIPER FROM AFRICA

The scales are large and foliate. The whole habitus and color serve strikingly for concealment.

FIG. 42. AN HETERODON OR SPREADING ADDER TAKEN AT SEBASTIAN, FLORIDA

The snake is making itself appear as terrifying as possible. The elongate fang-like teeth on the *posterior* part of the jaw bones are even made to show. A harmless but not a useful species for it feeds largely if not wholly upon toads.

FIG. 43. A WILD COBRA PHOTOGRAPHED NEAR LUCKNOW

Showing the extreme height to which the snake may raise itself, the "hood" being fully expanded.

FIG. 44. THELETORNIS, AN AFRICAN FOREST TREE SNAKE

It spreads its brilliantly colored neck vertically as a minatory gesture.

of shed castings of the terminal spinal button, forming in the aggregate the rattle (Fig. 39). Whenever this is agitated, it makes the familiar half metallic, half insect-like sound.

Thus, in a few words, a long and slow process may be recapitulated, but why, indeed, has the rattle been produced, or why do snakes vibrate their tails when they are frightened or disturbed? We know from experience that species living among dry leaves make a considerable noise in this way, but the rattlesnake, living in the open grassy plains, would not do so. Surely the rattle is not needed to warn away the snake's prey. No such altruism need be considered. The rattler lies in wait, striking the rabbit or bird upon which it feeds, then withdraws without rattling, to wait for the prey to die. At first sight, man seems to be the snake's only enemy, but the rattler is, of course, far older than man on this continent. What native animal, then, had the rattlesnake to fear on a wholesale scale, which coincided in its distribution with the area where these snakes may conceivably have been evolved? Ancestors of the wide-ranging bison fulfill these conditions, and we know that there were earlier bisons, for their fossil remains have been found. They were probably widespread also, for the remains occur in Michigan, Kentucky, and many other States. The hoofs of these ponderous animals, traveling over the plains, must have been distinctly dangerous to snakes living in the open, while the snake's bite would be distinctly unpleasant to the bison, although death would probably have rarely ensued. The bison would gladly keep out of the snake's way if warned, and this warning the rattle gave.

It has been suggested that the rattle served some purpose for signaling between the snakes, perhaps a mating

call or an assembly call for group hibernation. This is not a fact. In the first place, abundant opportunity for observation has never shown it to serve such a function; and, again, recent experiments have shown that the rattlesnake's hearing is confined to a range of sounds of wave length far different from that of the rattle. Thus the snake is deaf to the noise of its rattle.

Spitting snakes. Let us seek other environmental conditions and see whether elsewhere some such protective arrangement as the rattle has developed. The open veldt of Africa is the only other region in the world where snakes abound and where hoofed animals graze in great numbers. Snakes probably found the heavy antelopes equally dangerous though unwitting foes, and many antelopes probably suffered from snake bite. Here no rattle was evolved, but some of the common veldt-ranging snakes secured protection in another way. A number of the Elapine venomous forms learned to expel their poison in a fine spray to considerable distances and with a fairly shrewd aim at the eye. The poison is not caustic. The skin is unaffected, but the moist eye allows of an absorption so rapid that sharp pain and temporary blindness instantly result from the contact. Gardeners who work over shrubbery sometimes come into the hospitals at Bulawayo and other South African towns with acute inflammation of the eye-membrane (conjunctivitis). The Cape Dutch call one of these snakes (Sepidon) the *spuw slang*, or spitting snake, a misnomer, however, as the saliva is not involved. The natives know the habit well and greatly fear the spitting snakes, and, while of course this habit gives man added incentive to kill the reptiles, nevertheless against herds of grazing ruminants the protection obtained is no doubt perfectly efficient. Thus, aided by a warning sound, or by the in-

fliction of transitory pain upon its enemy, the snake is protected at the time of its most frequent danger.

The same spitting habit has been recorded several times from captive Indian cobras, and even Russell's Viper has been known to throw a spray of minute drops of poison by exhaling a sudden blast of air from the glottis against the fine poison as it comes from the fangs. Our rattlesnakes and the Gila monster (*Heloderma horridum*) also at times make use of this habit.

Coloration. A coloration that blends with the most frequent environment is common among all groups of animals, and while we must confess that this phenomenon is probably to a great extent due to a fortuitous blending of the individual's colors which by chance has a protective value, nevertheless there are many cases where the similarity of color is correlated with some peculiar habit and where beyond doubt chance variations have proved to have a very definite selectional value. Examples are the green snakes of many groups, living in bushes and tree-tops. Our familiar little green snakes, Cyclophis and Ophiodrys, are examples of this coloration, but their dress is less vivid and striking than that worn by the African tree viper Atheris (Fig. 41), where the very scales are enlarged and foliate in appearance. Some of the tropical green species are long and thin as a whiplash and move with lightning rapidity, stopping and starting with that peculiar precision which seems mechanical and not animate. These snakes may extend themselves from some leafy branch, and, remaining perfectly motionless, look like a dead twig. Such green whip-snakes are lizard feeders, and the green tree viper feeds on tree frogs — prey which is not specially shy or hard to secure. Why, therefore, any special use is found in this protective color is indeed hard to under-

stand, when so very many species of similar habits are gayly dressed. The coloration of animals offers a fascinating field for speculation as to the origin, service, and interpretation of the patterns and colors observed, but the subject remains, and always will remain, a matter of speculation only.

The habit of curling up in a tight ball to protect the head (Fig. 127) is another habit not only of many of the constrictors like the ground boas (Tropidophis) of the West Indies and (Lichanura) California, the sand boas (Eryx) of the Old World deserts and the curious Calabaria of West Africa, but often of other snakes.

Odor. Many snakes, notably our common North American garter snakes, may emit a singularly unpleasant and clinging odor. This arises from a milky viscous liquid emitted by glands situated in the cloaca near the vent. The snake when picked up by a dog or fox writhes about and soon besmears its body with this pungent and most fetid secretion; all students who must handle snakes know it well. It cannot be projected, but it has a high value as a protective device.

Such a device is well known among mammals where the several skunks have developed a very characteristic scent which can be sprayed in defense. The little zorilla in South Africa and the badger-like Mydaus in Malaysia each have a similar odor, and, curiously enough, though they are distantly related, have the typical black-and-white skunk markings. This is difficult to explain when other stinking mammals are not colored in this way. Any one who has ever skinned an old male mink knows that all evil-smelling mammals are not colored as skunks are. It may be that the key to the riddle lies in the fact that in the black-and-white group scent is definitely protective and is possessed

by old and young and by male and female. Among the others it may be, indeed seems always to be, in greater degree an attribute of the adult male. In other words, it is a secondary sexual character. Most ordinary mammal scents are probably for purposes of assembly and recognition. But why the sprayers of an evil odor should be striped black and white is still far to see.

In male crocodilians of several species there are glands on the skin of the neck that give off a musky odor. Lizards and amphibians, on the other hand, are markedly free from any odor offensive or otherwise. The birds vary considerably in this respect, but an odor of any real protective value is rare if it can really be proved to exist at all. Some insects, of course, are markedly fetid.

Burrowing snakes. Snakes living wholly under ground tend to become eyeless, almost tailless, and to have smooth, pavement-like, instead of overlapping, scales. Frequently the snout is tipped with a trenchant rim or flange doubtless of much use in subterranean progression. Some blind burrowers of the Typhlopidæ and Leptotyphlopidæ live in white-ant nests. Being very smooth and hard, they cannot be injured by the ants, while the latter afford a supply of food constantly at hand.

Some other snakes which, though often taking refuge under loose sand, still spend much time on the surface and probably pursue their prey there, develop a wide spatulate or shovel-like snout, but remain otherwise quite unmodified. Examples of this development are to be seen, remarkably similar superficially, in Phyllorhynchus and Salvadora in the New World and Lytorhynchus in the Old.

Tree snakes. Tree snakes, which actively pursue their prey and do not wholly procure it by lying in wait, have slender bodies and long tails: such types, among many

others, are Dryiophis in Asia, Langaha in Madagascar, and Oxybelis in Central America. So also the ground racers are very slender and incredibly swift. None of these snakes is known to strangle its prey by coiling about it. As with our black snake they may press it against the ground with the body if it struggles while being swallowed, but these racers are never true constrictors.

All of the boas and pythons and some others, such as the members of the genus Elaphe, which includes our chicken, corn, and pilot black snake, kill their prey by strangling. They maneuver the body so that the forward part lies free and is not coiled upon itself. They seize with a lightning-like thrust and, as soon as the teeth have sunk into the victim, contract the muscular body till both snake and prey are moved together. Coil after coil is then thrown about the victim, which soon suffocates. These snakes have prehensile tails that serve to prevent their falling to the ground after lunging upon and coiling about some tree-living creature. They do not, however, hang festooned from forest branches to draw the unwary traveler up to a dismal death among the tree-tops, as so often pictured. An able-bodied man can hold and carry away a constrictor up to ten feet long by grasping the neck with one hand and the posterior part of the body with the other. His hands must then be held well apart, and he should be careful not to let the snake get a loop around his neck or to start coiling about the hand which holds the neck, or the member will surely weaken and grow numb, and then the snake may get enough neck free to strike at his face. A snake twenty-five or more feet long requires a man for about every four feet so that it may be kept quite straight. This must be remembered at all costs, for a single coil of a large snake may cause great injury even if it is very promptly removed.

Spreading and inflating snakes. Many snakes have developed the posturing and inflating of the body, doubtless to make them appear more threatening and to save them from danger. Our common hog-nosed snake [1] (Fig. 42) spreads itself out flat, opens wide its mouth, and assumes an extremely threatening position. This snake, however, is perfectly harmless, and, if lightly struck with a stick or turned over, it lies absolutely still on its back without even breathing, so that the semblance of death is remarkable — unless it be turned back, when it at once flops over again. Other species puff up their necks or expand in a thin vertical plane, or, as in the familiar case of the Indian cobra [2] (Fig. 43), the anterior ribs of the neck are drawn forward by the muscles so that the region just behind the head is spread out to a marked degree, and the snake, which rises when alarmed and waves its body from side to side, is made much more threatening in appearance than it would otherwise be.

Lorenz Müller, of Munich, was the first to describe the remarkable habit of Theletornis (Fig. 44) of the Congo:

> If one should annoy the snake, something very remarkable happens. It raises itself, lifts threateningly the fore part of its body and swells its neck greatly. The neck only is distended by this inflation, so that it appears laterally compressed. . . . The neck of the snake . . . appears in the inflated condition dazzlingly light with dark bands, and I consider it very probable that a natural enemy is in no slight degree terrified by this sudden appearance of the brilliantly banded fore part of the body. . . .
>
> It is, in fact, a very surprising sight when the snake, which before was scarcely to be distinguished from a liana, lifts up the fore part of its body and shows among the foliage its inflated and

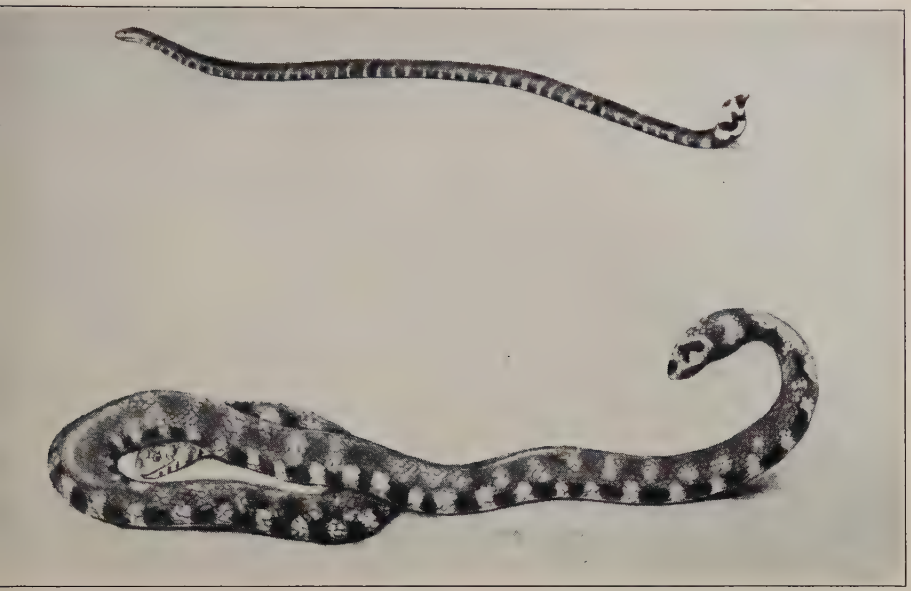
[1] There are several species of hog-nosed snakes or spreading adders, all North American and of the genus Heterodon.

[2] There are a number of subspecies or geographical races of the common cobra (*Naia naia*).

brilliantly colored neck. The strangeness of the sight is enhanced by the coloring and the peculiar movement of the tongue. The tongue is a glistening vermilion with shiny black points; these points are capable of spreading apart until they form an angle of almost 180°, and then in turn may approach one another until they merge completely. When excited, the tongue, with adpressed points, is stretched far forward. In this position it is held for a long time motionless, then the snake bends the tongue slowly upward and backward, while the points spread far apart. . . . Suddenly the excited animal lunges forward to strike the disturber of its peace. As long as the object of its anger is present the snake retains its warning attitude.

Now, while this snake is harmless, there is another snake of very similar appearance whose bite is said by authorities to be 'invariably fatal,' and this is the mamba, of which there are several species, black and green. These mambas, like Theletornis, are arboreal and often conceal themselves in the foliage of trees overhanging wood roads and trails, and while the mamba needs no protection and is universally feared, it, too, has this habit of inflating vertically, not spreading itself horizontally as its close allies, the cobras, do.

Noble has shown that the mechanism by which these snakes inflate is not the complicated mechanism of air sacs and tracheal valves that has been described for some of the Old World chamæleons, which are wont to puff up their bodies when angry; but instead they inflate the membrane that covers the dorsal portion of the trachea between the free ends of the halves composing the tracheal rings on each side. This is very much thinner than the sheath of tissue that binds the successive tracheal rings into a continuous tube, and so is easily expanded. Thus presumably in all these snakes inflation is accomplished by first taking air into the lungs and then, with the glottis closed, con-



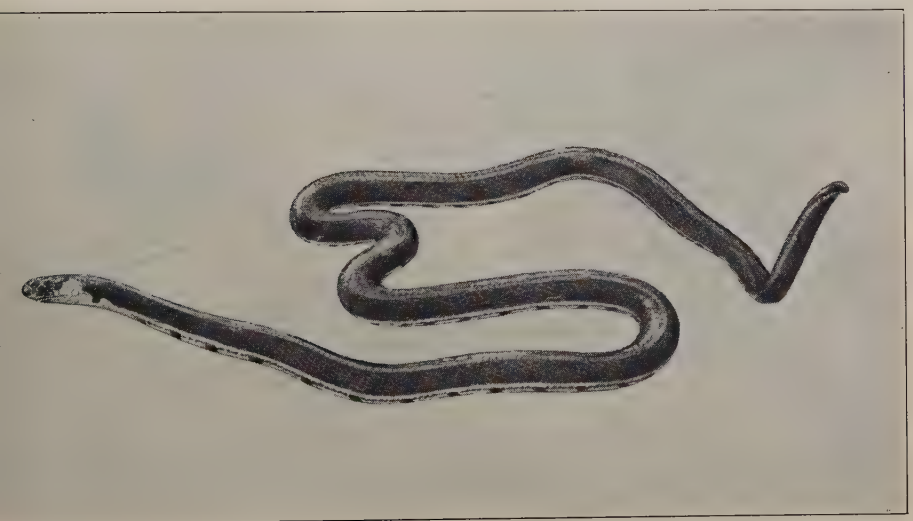
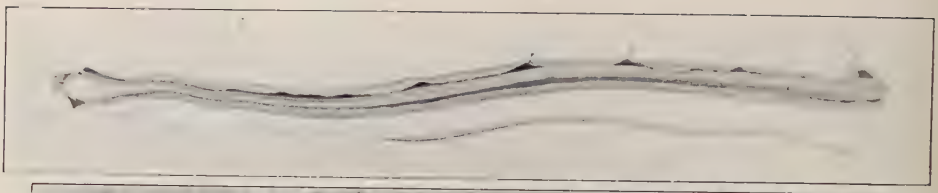


FIG. 45. CYLINDROPHIS RUFUS, A HARMLESS MALAYAN SNAKE WHICH CARRIES ITS RED-SPOTTED TAIL ERECT AS IT CRAWLS, AFTER THE MANNER OF THE POISONOUS DOLIOPHIS

FIG. 46. A VENOMOUS SNAKE FROM MALAYA, DOLIOPHIS INTESTINALIS, WHICH ALSO CARRIES ITS TAIL ERECT

The tail is red on the lower surface and is moved from side to side as the head might be.



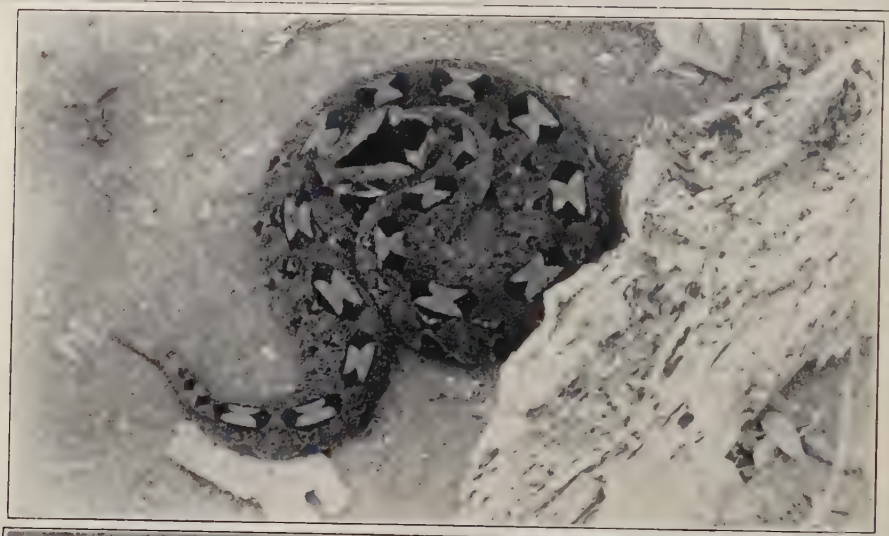


FIG. 47. THE POISON GLAND OF DOLIOPHIS, DISSECTED OUT TO SHOW ITS GREAT LENGTH

FIGS. 48 AND 49. BITIS NASICORNIS, THE RIVER JACK OF WEST AFRICA
One of the most venomous snakes known.

tracting the powerful body-muscles so that the neck region is distended while the trachea balloons out. One African species (Dispholidus) is able to inflate not only the trachea but the lungs, until it looks like an enormous sausage. This power to expand vertically has been attained by a number of unrelated groups of snakes, as has also the power to flatten the neck, after the manner of the cobra (Fig. 43).

Mimicry in snakes. No more threatening gesture is to be found than that seen in two East Indian snakes, totally unrelated to each other. One, Cylindrophis, a primitive burrower and entirely harmless, when it is brought above ground travels along with the tail bent sharply upward (Fig. 45). The under surface of the tail is brilliant red, and if the snake is touched the upturned tail snaps around in a threatening manner, precisely like a striking head. The other snake, *Doliophis intestinalis* (Fig. 46), which does this same thing, is quite similar in habit and coloration, and, while this species is so small that it could not possibly bite any large animal, it must nevertheless be extremely poisonous, for almost no other species has such gigantically developed poison glands (Fig. 47), which are not confined to the head, as they are in most snakes, but extend far down into the body cavity, even pushing the heart out of place. An African viper, Causus, has similarly elongated glands — *cui bono?*

Only recently discovered and of remarkable interest is a genus from Brazil, called Apostolepis. This snake has the habit of Doliophis, that is, it has the form and general appearance of that genus; but, instead of being dark-bodied and red-tailed, the whole snake is vivid red, the head and tail alone being black. The position in which some freshly killed specimens recently reached the Museum at Cambridge shows apparently that the tail is held straight up in

the same way that I observed Doliophis in Java to do, and as Annandale and I found that Cylindrophis did in the Malay Peninsula. The use or significance of this habit is not fully understood. It causes the tail to appear more head-like than the head; this in itself may have some protective value. It may also serve some helpful purpose by making the snake look more dangerous than it really is.

In these snakes we see what is called mimicry. There are many cases where a harmless species apparently mimics a poisonous one. This is also a common occurrence in insects, where a stingless form simulates one with a powerful sting, or a succulent species, one having an evil taste. The origin of this mimicry is very difficult to understand and has never been well explained. Why should the New World abound in snakes banded red, yellow, and black, both poisonous and harmless? In every region where a poisonous banded form occurs there is a closely similar harmless form, but the converse is not true, for many harmless and banded forms are found where there are no similar poisonous ones. Banded coloration is rare in the Old World. Why should we suppose that the American environment favors the production of red in snakes? We might just as well ask why are the tropical American forests inhabited by an astonishing number of animals having prehensile tails — snakes, monkeys, carnivores, rodents, marsupials, and edentates? It may possibly be that forests have been more widespread and persistent in tropical America than in the Old World tropics. There is no possible use in speculating. We must frankly admit that we do not know.

In deserts everywhere snakes tend to become pallid and gray, as do the mammals and birds. They also tend to become rough and scabrous, and for some reason to have

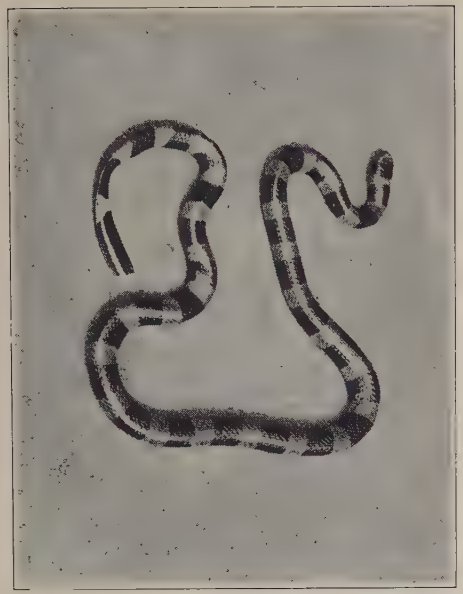


FIG. 50. A SEA SNAKE (LATICAUDA LATICAUDATA)

The sea snakes are essentially water cobras but they are wholly aquatic. They have no belly scales, since they never crawl; they have paddle-like tails and valves in the nostrils, for they dive deeply when pursued. This species brings forth living young at sea, as do most if not all its allies.

FIG. 51. A TWO-HEADED SNAKE

These monsters rarely live more than a very few days.

FIG. 52. MARINE IGUANAS AT GALAPAGOS ISLANDS

FIG. 53. GALAPAGOS LAND IGUANA (CONOLOPHUS CRISTATUS)

horns above their eyes which can serve no conceivably useful purpose. Indeed, horns on the eyelids have been assumed by innumerable reptiles and amphibians of almost every group somewhere within its range, and, moreover, a single horned species or two are often found in a group that is normally hornless. Horns on the nose are far rarer, but occur in some vipers like the fearful River Jack of the Congo, *Vipera nasicornis* (Figs. 48 and 49).

Other adaptations for protection. While most snakes are silent creatures, some species can hiss almost as loudly as escaping steam. This is true principally of the great heavy-bodied species having a large lung capacity and powerful musculature. Sound is also produced in one other curious way. Some of the desert vipers of northern Africa and Arabia, strange, pallid, almost white creatures, called Cerastes, and their allies, have the habit of flattening out the edge of the body like a lateral flange which is capable of considerable movement and with which they dig up the sand and toss it upon their backs so that they sink out of sight in a most surprising way. In these species the scales along a narrow zone on each side of the body are tipped sharply upward, and when these scales are rubbed against the adjacent normally formed scales, a sharp swishing sound is produced which may have some protectional value. Some geckos chirp and cluck, as do some land tortoises, and old male alligators roar almost like lions, but, generally speaking, voice is poorly developed in the whole reptilian series.

In mentioning (p. 22) the sea snakes [1] (Fig. 50), we spoke of the valves in the nostrils and these have been also developed in many unrelated groups where the species have taken up aquatic life.

[1] All members of the family Hydrophidæ.

Later on (p. 62) we shall have something to say about flying lizards and frogs, but a flying snake is even more surprising. Chrysopelea in Malaya, Sumatra, and Borneo, glides in the same way that our flying squirrel glides. The snake when pursued by some ophiophagous hawk launches itself from a high limb and, by spreading its ribs and drawing in its belly and remaining perfectly rigid, it glides slowly away at an angle and reaches the ground with very little jar.

Many different environments are being, or have been, invaded by totally unrelated stocks, and in a surprising number of cases the invasion of a similar habitat by different groups is accompanied by the assumption of similar habits and the appearance of similar somatic modifications. We have to acknowledge our considerable ignorance when asked concerning the causes which have brought these astonishing parallelisms into being.

Abnormalities in reptiles. Abnormalities, of course, occur in reptiles as in all other animals. Double-headedness (Fig. 51) or axial bifurcation is very surprisingly common. The figure shows a specimen of the common Eastern king snake with two heads. Two tails are unknown in snakes, but among lizards, where the tail is often loosely attached and easily cast, it may be only partially separated and a new tail may grow at the wounded point, so that forked-tailed or even three-tailed lizards are not uncommon.

At first sight it would not seem possible for snakes to vary in much but size and color, yet really remarkable variability exists in the group and marvelous developments have been attained, though by infinitely slow degrees, to enable these fascinating creatures the better to fit into the environmental niche pointed out to each plastic form by the inevitable finger of evolution.

CHAPTER IX

ADAPTATIONS OF LIZARDS

The possession of limbs by lizards and their more normal or less highly specialized feeding habits, as compared with snakes, have opened a vast number of pathways wherein many different groups have assumed a surprising variety of forms. While no lizards have become completely aquatic, as have the sea snakes, there are nevertheless many types which enter the water freely, some diving when pursued, others running upon the surface of the water; still others swimming freely in their ordinary journeys from place to place. Only one species enters salt water, and this is the so-called marine iguana of the Galapagos Islands (Fig. 52). These remarkable creatures, reminding one in miniature of the gigantic reptiles of past geologic times, live in great herds along the sea cliffs of the islands, where they feed exclusively upon marine plants (algæ). In climbing about on the rocks at low tide, they are often completely covered by the wash of the high billows of the restless Pacific.

Inland a closely related genus (Conolophus) lives in burrows and feeds upon the blossoms of the cacti. These great lizards (Fig. 53) are sluggish, but many species move with a rapidity almost unbelievable, darting off so quickly that the eye can hardly follow their movements as they start and stop with mechanical precision.

In the high forests of Central America the so-called basilisks, Basiliscus (Fig. 54) and Læmanctus[1] (Fig. 55), abound about the shores of the fresh waters, and when disturbed rush across the surface with a most curious gait,

[1] All of the family Iguanidæ.

standing fairly upright with the fore feet folded against their sides and the tail raised as a counterpoise. These lizards never dive, but a related lizard in Cuba, Deiroptyx, rushes off in this same way, and, having reached some quiet nook away from the pursuer, sinks quickly to the bottom, where it remains until danger is passed. The species of Tropidophorus [1] in southeastern Asia often creep into the streams near which they live and escape by hiding among stones under the water.

Bipedal locomotion has been taken up not only by runners over the face of the water, but by a number of strictly terrestrial species as well. In Australia the strange frilled lizard, Chlamydosaurus [2] (Fig. 56), runs through the forests of Queensland securing safety by flight. When cornered, it makes a stand, and these strange frills of skin around the neck (Fig. 59) are one of the very few cases among lizards where there has been an apparent modification of bodily form purely for purposes of threatening or terrifying. The frills lie unapparent, pressed close to the neck, until they are fanned out.

In our Southwest there are a number of desert lizards belonging to the family of the iguanas, many of which also run on their hind legs (Fig. 57). In South Africa the gecko, Ptenopus, lives in similar situations. It is interesting to point out the remarkable similarity in foot structure which has been acquired by these two wholly unrelated types. The long slender toes, commonly found among Iguanids, but extremely rare in geckos, are in Ptenopus,[3] as in Uma,[4] for instance, provided with combs of fine elongated scales which offer a more resisting surface to the powdery sand (Fig. 60).

[1] Of the family Scincidæ.
[2] Of the family Agamidæ.
[3] Of the family Gekkonidæ.
[4] Of the family Iguanidæ.

IGS. 54 AND 55. BASILISCUS (ABOVE), LEMANCTUS (BELOW), TWO TYPES OF LIZARD VERY CHARACTERISTIC OF THE CENTRAL AMERICAN FORESTS

Basiliscus runs on the surface of the water sometimes for many yards.

FIG. 56. THE FRILLED LIZARD OF AUSTRALIA

When it runs it uses its hind legs only.

FIG. 57. THREE INSTANTANEOUS VIEWS OF CALLISAURUS, A LIZARD FROM THE SOUTHWESTERN DESERTS OF AMERICA

This shows bipedal locomotion.

FIG. 58. SCINCUS OFFICINALIS, A LIZARD MODIFIED FOR LIFE UNDER AND NOT ON THE DESERT SAND

Note the sharp wedge-like head, very smooth scales, and degenerating limbs. An Egyptian species In allied forms the hind limbs may be mere stylets or disappear, while the fore limbs are also ofte completely lost.

Many lizards have invaded the deserts, and it is extremely instructive to note the results that have come about through desert life. Those invading forms belonging to the active, swiftly moving families have either become even swifter, or, in the case of the more ponderous species of these same groups, they have developed strong defensive powers. The tail, used as a lash, is armed with heavy, powerful spines (Figs. 61 and 62). Indeed, as with snakes and insects and even plants, many desert lizards, as we have said before, tend to become extremely spiny. Our common horned toad and the rarer Australian Moloch (Fig. 63), as well as the Zonures (Fig. 64) of South Africa are cases in point. When, however, sluggish, retiring groups, such as the skinks (Fig. 58) or similar forms, enter the desert, they become modified for rapid burrowing or even swimming, as it were, into the loose sand. The almost legless Neoseps of Florida is a fine example of the sand swimmer.

The similarity of appearance of these spiny forms, as seen especially in Figs. 61 and 62, emphasizes the way certain 'cognate' families in the Old and New World have come to be of similar appearance through specialization to meet the same environmental demands. Moloch (Agamidæ) looks very similarly to our horned toads (Phrynosoma of Iguanidæ). The spiny tails figured are strikingly similar. Cursorial types like Liolepis (Agamidæ) of southeastern Asia looks like Dipsosaurus (Iguanidæ) of our Arizona deserts. Other examples in other families could be cited, and it is difficult upon seeing the creatures side by side to believe that there may be fundamental internal characters separating species which superficially are almost identical.

Reduction of limbs in lizards. The lizard may drop one, two, or even all the digits until the limbs become simply

stylets or fin-like flaps or short paddles; in other cases they may be lost altogether, or only one pair of limbs may disappear, but usually the fore limbs are the first to go. A few species, however, have retained the fore limbs and lost all vestige of the hind pair. Almost every conceivable permutation and combination in the reduction or loss of some or other of the fingers or toes may be found. A single compact genus may have closely related species, some with normal digits fore and aft, and others showing partial or complete loss.

While a few known forest skinks are arboreal in habits and have long slender tails, some of the species have the tail reduced and in some it has almost completely disappeared. The desert skinks have also acquired another remarkable modification in the form of a window in the lower eyelid. In some species this window is a simple round transparent disk; in others it occupies the whole eyelid and the lid itself is permanently closed and fused with its fellow. It is the lower lid invariably that is modified in this way, which, of course, is a great protection from blowing sand.

The African chamæleons[1] (Fig. 65) are marvelously modified for arboreal life; their prehensile tails and toes and fingers are joined into permanently opposed bundles for grasping twigs. These creatures carry on their heads just such a strange type of ornamentation (Figs. 66–70) as was shown by many of the huge fossil dinosaurs, and it seems not improbable that they are able to survive with such ornaments only because of their small size and the commensurate size of the ornaments, for the small beast has a tremendous musculo-mechanical advantage over the large

[1] Three related genera, all vulgarly called chamæleons, namely, Chamæleo, Rhampholeon, and Brooksia, unitedly form the Rhiptoglossa.

FIG. 59. CHLAMYDOSAURUS, A LIZARD FROM AUSTRALIA AND PAPUA

FIG. 60. A. FOOT OF PTENOPUS FROM SOUTH AFRICA; B. FOOT OF UMA FROM ARIZONA

Both are similarly modified to aid in running over loose sand. The lizards themselves are most distantly related.

FIG. 61. CACHRYX, AN IGUANID LIZARD FROM SEMIARID YUCATAN

FIG. 62. UROMASTIX, AN AGAMID FROM THE DRY REGIONS OF UPPER INDIA

Similar in many details, though they belong to different families.

FIG. 63. MOLOCH HORRIDUS, A SPINY LIZARD OF THE AUSTRALIAN DESERTS

The relation of desert life as a cause of spinosity in plants and animals is very incompletely explained. This is an extreme example of the spinosity of a deserticolous species.

FIG. 64. ZONURUS, AN AFRICAN LIZARD

Showing the spinosity so characteristic of desert species.

one. Such garish decorations often are detrimental to the persistence of a group which starts on this path of orthogenetic variation. The high elevated casque, the long horns on snout or orbits, or indeed on both, and the wide dermal lobes of some species only need a more extensive ossification to convert the whole aspect into one most astonishingly like such a creature as Triceratops. This beast was as large as a rhinoceros, and its stock or phylum got running to bulk and armament, probably to the great detriment of its probability of survival. They certainly disappeared very suddenly and left no survivors.

The geckos [1] are usually nocturnal, living among crevices or rocks, on the trunks of trees, or even frequently invading buildings. The whole family is singularly homogeneous in appearance, and, as is not the case with several other groups of lizards, it is usually possible for a person who has seen half a dozen species of geckos to recognize most of the others when they appear. They are usually rather small, flattened lizards (Fig. 71), of sluggish movement, pallid colors, and with large cat-like eyes. Their feet are usually provided with plate-like lamellæ which are very variously arranged to produce a vacuum beneath the digits and so aid in climbing (Fig. 72). Still, in the matter of size there are exceptions, for some geckos are a foot long. Indeed, the plasticity of this group in meeting divers environmental conditions has made it, with the possible exception of the chamæleons, by far the most interesting to the herpetologist.

In one African genus called Lygodactylus, the tip of the tail has developed a perfect sucking disk which functions as a fifth foot, and Loveridge, writing from Tanganyika, says that one of these tree-climbing lizards struck stone-

[1] Members of the great and widespread family of Gekkonidæ.

dead by a sharp blow from a cane may let go its foothold and remain hanging from the bark supported by the caudal sucker.

Geckos' eyes are very beautiful: large, usually without lids, and staring. The pupil may be round, but more often it is elliptical, and in many genera it is strangely polygonal, and one wonders what bizarre impressions must be conveyed to the lizard's brain. As with most lizards, these can vary their coloration and their metachrosis is very purely protective. A strange feature is the uninterrupted passage of light through the gecko's head from ear to ear. There is no bony structure to interfere and a gecko's head, silhouetted against a bright light, appears to have a window in it.

In the tropics geckos come regularly at night to lamps, attracted by the insects which settle about the lights. Most geckos have voices and utter their cry quite without warning, repeating it from five to fifteen times. In Burma, every temple and monastery has its pet 'tookay,' a great fat gecko living in the roof crannies and feeding largely on cockroaches. From time to time during dusk and night these prowlers may bark out a loud '*tu-u-u* káy,' the last syllable sharply staccato. Since the calls come unexpectedly and vary greatly in number, the holy folk have a simple and even a most useful betting machine always at hand, and many a hot, drowsy evening is passed in this innocent gambling, small wagers being laid on the number of times the lizard will call.

The feet of geckos exhibit many variations of great diagnostic importance, from those of such a type as Ptenopus, living on the sand, through all the forms whose feet are modified for suction by having the transverse lamellæ differently developed, to the extreme type seen in the exces-

FIG. 65. AN AFRICAN CHAMÆLEON

Note the prehensile tail, the digits bound into two opposable bundles, and the eye-slit. The eyes move independently. This represents extreme specialization for life in trees. The creatures move slowly and deliberately.

FIGS. 66–70. THE HEADS OF FIVE SPECIES OF AFRICAN CHAMÆLEONS TO SHOW DIFFERENT TYPES OF ORNAMENTATION

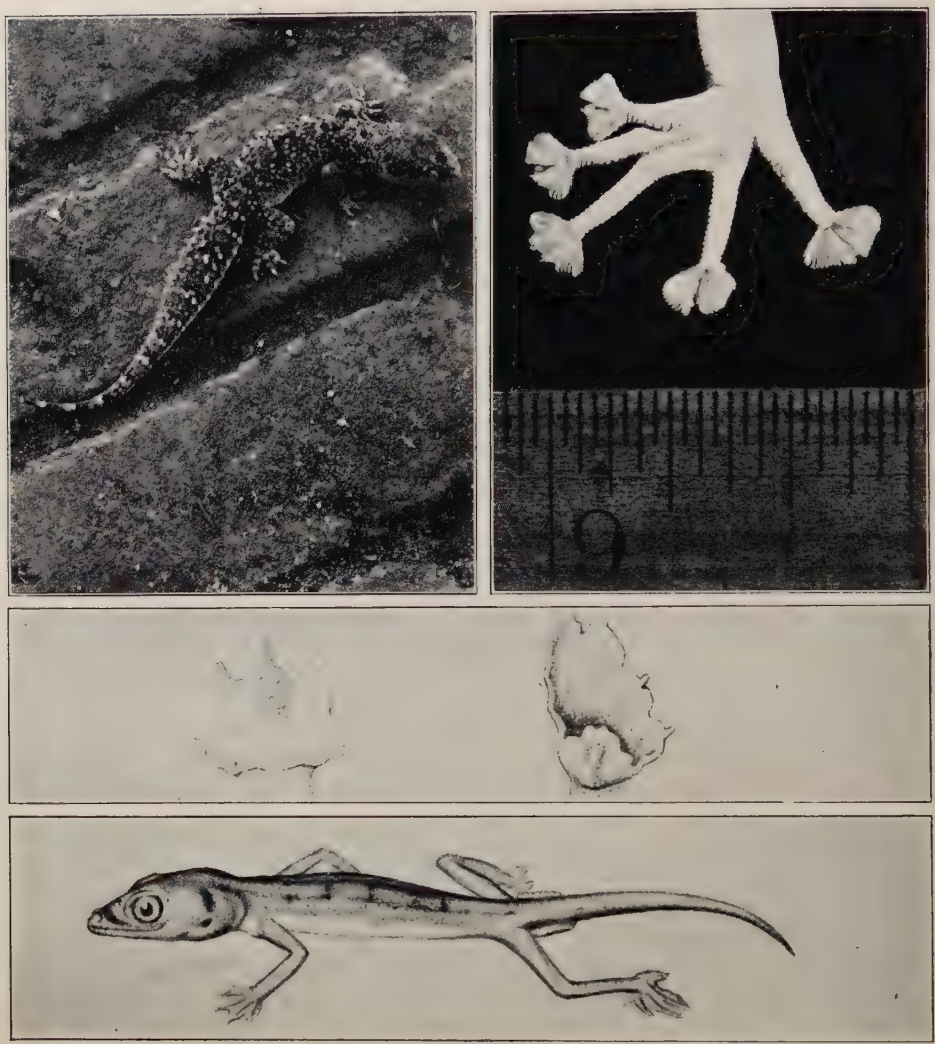


FIG. 71. A TYPICAL GECKO, AN AFRICAN TARENTOLA

FIG. 72. FOOT OF A PTYODACTYLUS

Well adapted to clinging to smooth rocks. This Gecko is found in North Africa, Arabia, and Palestine. Geckos' feet show an infinite number of modifications of this general method of securing a firm foothold.

FIG. 73 (*a* AND *b*). PALMATOGECKO OF THE NAMIB DESERT OF SOUTHWEST AFRICA WITH FORE AND HIND FEET MAGNIFIED

sively rare Palmatogecko (Fig. 73), known only from the North Kalahari Desert of Southwest Africa. This astonishing ghost-like form, instead of having become thin-fingered and -toed, like Ptenopus, for the sake of agility, has curious duck-like web feet which are probably equally useful as it runs swiftly and dives rapidly into the sand to escape pursuit. It is remarkable that the two extremes of foot structure are shown by desert-living types, for a desert environment in general is little favored by this family.

Self-mutilation in geckos. The tails of the geckos may be simple, that is, normal in form, or they may be strangely and fantastically expanded and developed to aid in a scheme for protection. This is marvelously shown in the Australian Phyllurus (Fig. 74), while another species, living in the same region, has aborted its tail until it is merely a little knobby stump (Fig. 75). Lizards' tails serve two perfectly definite purposes. In some cases they are weapons of defense, capable of being swung with terrific force, as in the large iguanas and monitors; in some desert species of several families powerful tails, armed with sharp, heavy spines, are no mean weapon (Figs. 61 and 62). In a great many other cases lizards' tails appear to be most useful simply in that they can be thrown off at will. This is accomplished by a sudden tetanic contraction of the bundles of muscle fibers that attach one caudal vertebra to its fellow. The muscle pull is usually accomplished by a quick movement of the tail which breaks the skin and leaves the member snapping and tossing about like an agonized angleworm. This motion lasts for some little time and is very conspicuous, since many of the genera and species, which especially practice autotomy, have sky-blue tails. A predaceous creature, making a snap at the lizard, finds itself at once interested in this gaudy gyrating member,

while the lizard has an excellent chance to make good its escape.

In some of the anguid lizards [1] the body itself is very short, while the tail forms the greater part of the creature and may break into several wriggling pieces, thus allowing the relatively inconspicuous body to escape. These lizards are the so-called glass snakes, also known as blind worms in Europe, certainly most inapt names. However, the skin is hard and glassy and the broken pieces fairly crack apart. Country people have the idea that they join together again after the danger is past, which, needless to say, is quite impossible. Reproduction or regeneration of the tail, however, takes place regularly in all forms in which this self-mutilation occurs and offers a fascinating field for study. In the species where the tail is a vehicle for fantastic ornamentation the reproduced member is invariably furnished with a much more simple and undecorated squamation than was seen in the original (Figs. 76–78). The new tail is supported by a simple cartilaginous rod, for the vertebræ themselves are not regenerated. This rod seems to be similar in structure and function to the primitive vertebrate notochord (Fig. 79), and it is likewise not improbable that the character of the scales of the new tail bears similarity to that of some ancestral form. There is probably a recapitulation here of evolutionary stages passed through in the development of the stock which it would be fascinating to trace, but we know so little of the detailed geologic history of the modern groups of reptiles that such questions as this will probably never be solved.

Egg-laying. While the Anoles and the little tropical American house geckos of the genus Sphærodactylus apparently lay but a single egg, usually in the gallery in some

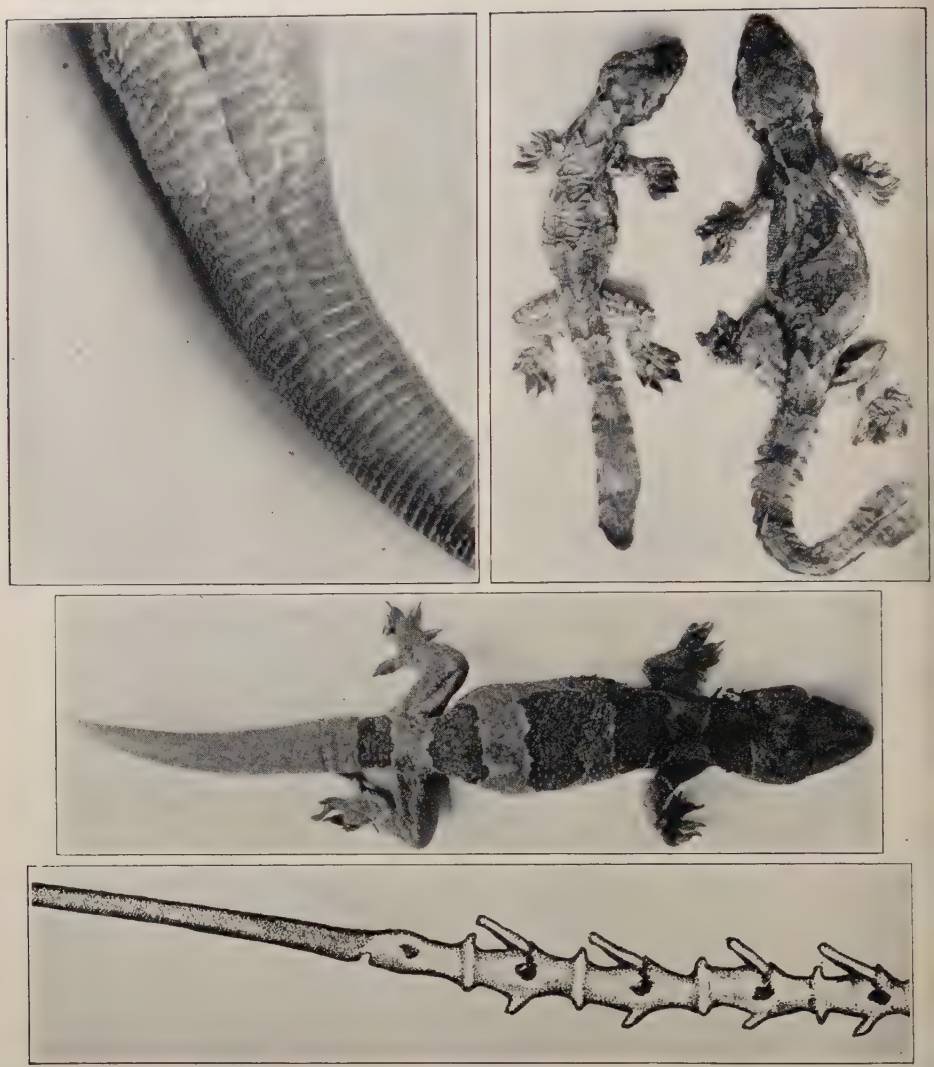
[1] That is, members of the family Anguidæ.

FIG. 74. PHYLLURUS, PROTECTIVELY COLORED FOR LIFE ON BARK OF TREES

The tail is flat and expanded. Found in Queensland.

FIG. 75. NEPHURUS, FROM CENTRAL AUSTRALIA PROTECTIVELY MODIFIED FOR LIFE ON OR AMONG STONES

The tail is a mere knob.



SHOWING THE LESS SPECIALIZED CHARACTER OF REPRODUCED TAILS IN LIZARDS

FIG. 76. The under surface of the area where regeneration began, showing the fewer and larger scales of the new-grown part in *Aristelliger*, a West Indian Gecko.

FIG. 77. The lizard (*Ptychozoon*) on the left has a new tail; note the smooth surface and unbroken outline. The one on the right has a normal tail with crenelated outline and ornamental tubercles.

FIG. 78. An African *Hemidactylus*, the new tail lacking cross bands of color and with undifferentiated scales.

FIG. 79. When the lizard's tail is broken off and a new portion grows, the vertebræ are not reproduced but a long cartilaginous rod supports the new-grown tissues.

decaying log, other geckos lay eggs stuck together in pairs, ⊂⊃, and adhering to the bark of trees. This is done by the American Aristelliger and the Old World Ptychozoon, the curious fimbriated 'flying' gecko, which does not fly. Thus they are evidently soft when laid, but when found they are covered with a white and brittle shell — most reptile eggs have a rather parchment-like covering. These egg pairs are slow hatching, and an observer in Java found that eggs laid in November did not hatch until May. These may be considered specialized ways of egg-laying, for most reptiles of all orders simply repair to some sandy, southern slope — railway embankments are favorite places — and there dig a hole, lay from six to perhaps thirty eggs and allow the sun to hatch them. Crocodiles and alligators pile up a heap of vegetable trash which warms as decay progresses and so helps incubation; and a few snakes coil about their eggs brooding them and giving them protection. This was first noticed when a certain famous python laid a large clutch of eggs in the Paris Zoo. She coiled about them as they lay in a sort of conical heap, and the most remarkable concomitant was the fact that there was apparently a true body heat developed during the period of brooding. As is well known, all reptiles and amphibians are ordinarily of the temperature of the surrounding environment at any given time.

CHAPTER X

ADAPTATIONS OF LIZARDS (*continued*)

Flying lizards. Almost all groups of the vertebrate kingdom have essayed aërial flight to some extent; birds, bats, and the volplaning or gliding flying fishes are familiar to all. For some reason the group of the Pterodactyls (Fig. 7), although seemingly marvelously perfect in the completeness of their adaptation for flying, failed to survive. Their wings were apparently as serviceable as bats' wings, although perhaps less well supported, for instead of most of the hand taking part in the spread of the wing through the elongation of the finger bones, in these flying reptiles the membrane stretched from only one greatly elongated finger and thence to the thighs. The other digits were short and bore hooked claws that doubtless helped the creatures to scramble about the rocky cliffs upon which they may well have dwelt. These flying reptiles have long since disappeared, and while the modern groups have all developed efficient gliders, none of them is a real flyer.

Wallace in his account of the flying frog unfortunately published a somewhat exaggerated drawing of the creature. Annandale, who had some experience with *Polypedates nigropalmatus*, was not able to substantiate the fact of its using its large hands and feet in gliding, as Wallace's Chinese boy assured him he had seen.

The so-called flying gecko (Fig. 80) was assumed to fly because of the curious flanges along the side of the body, but I had a great number of these lizards alive in Java and none of them ever showed the slightest willingness even to expand the membranes, no matter what opportunity was

offered. There is no bony or cartilaginous support, and it seems probable that, if the flanges are capable of expansion at all, they must simply serve as an addition to the remarkable equipment which the lizard possesses for protecting itself by resembling the bark on which it habitually rests; for with the side flaps spread there would be no shadow cast by the beast and it would appear simply as a slight gradual elevation on the surface of the tree trunk. Other geckos show much less developed flanges about the body, and it is entirely possible that this structure in Ptychozoon is simply another of those many cases where, through what Cope has called 'superabundant growth force,' a structure takes up a sort of evolutionary impetus or momentum which carries it beyond the stage of usefulness and sometimes to an absurd degree, beyond doubt harmful to the animal.

The following cases may be mentioned as instances of 'superabundant growth force.' The ancestral elephant's teeth served a useful purpose for digging up roots and bushes. They were short, strong tusks, and their owners were not long-legged giants. The tusks of existing elephants work with less mechanical advantage. They are very often broken in use. Again, the enormous curling tusks of the mammoth were simply fantastic, and could have served no useful purpose. Now the mammoth has disappeared, although its overgrown tusks may not have been the sole reason for its having become extinct. The sharp stabbing horns of many deer are useful weapons. The great horns of the moose and elk are far less serviceable, while the gigantic spreading antlers of the Irish elk must have been a terrific burden, not only to carry, but to grow anew each year after the shed. The Irish elk has disappeared, although again its enormous antlers may not have been the only reason. This excessive development is

a common phenomenon in reptiles especially, and many of these bizarre forms are beyond doubt due to this sort of evolutionary impetus or momentum.

One group of lizards, the members of the genus Draco,[1] have the ribs greatly elongated for supporting a wide membrane, and these lizards glide most beautifully. Indeed, they sail for great distances from the top of one tree to the bottom of the next, looking like fairy parachutes of gay and brilliant colors (Fig. 81). There are a great number of these small lizards in southeastern Asia and in the Malayan Islands. They seem to travel in little companies which often take flight at about the same time, even appearing at the same place day after day. They are ant-eaters, and so may perhaps make their regular rounds, a little company ascending one tree trunk to pick up the ants and then starting off to another tree to repeat the process. No types are known connecting this extreme development with other lizards. We know nothing of their genealogical antiquity, but they certainly are specialists far beyond all their fellows.

Protective devices in lizards. The changing of color is a prominent feature of many lizards, but this is by no means always protective. Indeed, it very frequently has emotional control and not infrequently a temperature relation as well. It is brought about by the distribution of pigment granules in certain octopus-like cells of the skin, the processes of which allow the granules to be brought into various relations with the surface of the animal and hence to become variously affected by the rays of light penetrating the translucent epiderm. Our little Southern chamæleon may be resting on a smooth leaf, the whole lizard vivid green. Grasp it, and it is not improbable that in a very

[1] Family Agamidæ.

few seconds you may find a dark brown lizard in your fingers. The African chamæleons (Fig. 65), with their long monkey tails, their curious slow movements and strange-looking limbs, their eyes like tiny slits each on the apex of a cone that moves independently of its fellow, to permit of vision forward and back or up and down at the same time — these curious creatures set with strange horns like tiny rhinoceroses and changing color almost from moment to moment as waves or blotches appear and disappear haphazard over their bodies — provide, I believe, the most fantastic objects to be seen among all land animals to-day.

Poisonous lizards. Among lizards there is less modification of dentition than among mammals, so that they are unable to bite and tear apart large prey or to engulf large animals as the snakes do. For this reason there has been less incentive to elaborate poison, for most lizards feed on small and helpless creatures, and we know of only one genus of lizards that is definitely poisonous, although the Bornean Lanthanotus is strongly suspected. The two Gila monsters (Heloderma), however, are really poisonous. They are curious-looking lizards (Fig. 82), confined to the desert of our Southwest, yellow or pinkish and black, the scales looking like beadwork. They apparently feed largely upon birds' eggs, so why they should need poison is hard to understand. Still they have it, and it is virulent. It is conveyed in a totally different way from snake poison, for in Gila monster [1] the teeth of the lower jaw are grooved and the poison oozes into the wound from a series of glands along the side of the lower jaw, while the lizard holds on with a bulldog-like grip. Ditmars records that at the New

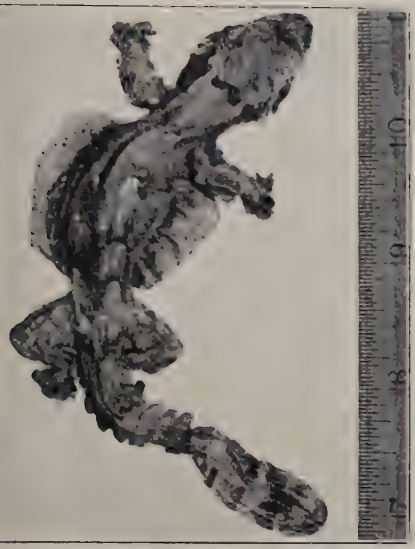
[1] The genus Heloderma, of the monogeneric family Helodermatidæ, composed of only two species, namely, *H. suspectum* of the southwestern United States; *H. horridum* of western Central Mexico.

York Zoölogical Park the Mexican Gila monster (*Heloderma horridum*), when it was disturbed, champed saliva and oozing poison into a foamy froth and then blew it toward the cause of its annoyance in a generous spray. This habit, so like the poison 'spitting' of some African snakes, is unique among lizards and is a striking example of parallelism in manner of defense.

Perhaps the most peculiar defense in all nature is that of the lizards called horned toads, which shoot blood from their eyes. These look much like the Moloch (Fig. 63). It is well known that fear or anger brings about increase of blood pressure, and here in the genus Phrynosoma the capillaries about the eyeball became greatly engorged until they finally burst, spraying droplets of blood for some little distance. The blood apparently has no poisonous properties, although it is said to be sour and unpleasant. All 'horned toads' do not squirt blood, but many individuals do and it is certainly most uncanny. Just how protective this may be is not known, but it certainly is one of the strangest of Nature's devices.

Another way in which reptiles may be shown in the future to have unexpected importance lies in the possibility that they may be reservoirs for the parasites of tropical diseases. Some of Dr. R. P. Strong's recent work in Panama points strongly to the possibility that lizards may be connected with the life-history of one of the organisms producing tropical ulcers, and it has been suggested that in Africa certain lizards are the sources whence the tsetse fly picks up the trypanosome of sleeping sickness.

The dewlap in lizards. Many lizards, especially of the family of the Iguanidæ, have great pendulous folds of skin on the chin and neck region. These serve to give their possessors a fierce and bizarre mien, but otherwise seem to



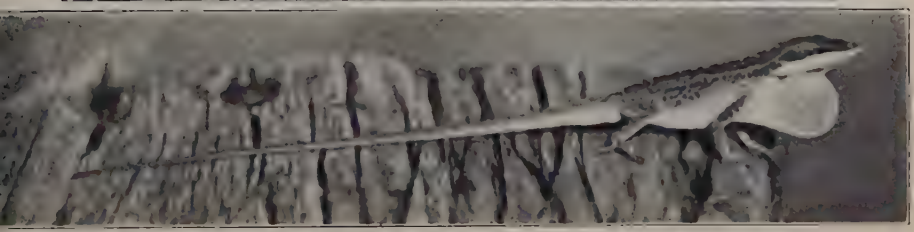


FIG. 80. PTYCHOZOON, THE 'FLYING' GECKO OF JAVA

FIG. 81. DRACO VOLANS FROM JAVA

Showing 'wings' expanded and in repose; this is typical of many closely similar species.

FIG. 82. A TAME GILA MONSTER

He is fond of egg, lapping it up with his tongue and then letting it run down his throat.

FIG. 83. ANOLIS NELSONI

Photograph from life at Swan Island in the Caribbean Sea.

FIG. 84. THE COMMON POND FROG, RANA CLAMITANS

A typical semiaquatic amphibian.

FIG. 85. A CHARACTERISTIC TRUE TOAD WITH THE USUAL WARTY SKIN: BUFO AMERICANUS

Taken near Cambridge, Mass. Note how well the style of color-pattern fits the natural surroundings.

have no special purpose. They are often called gular pouches, but they are scarcely real pouches, since they are without trace of open space within and they cannot be blown up as the throat pouch of a frog can be. A few genera, however, have elongated a hyoid stylet bone which may be extended by the contraction of a specialized set of muscles. When the stylus is so extended, it carries out a fan-like extension of elastic skin. This is almost always vividly decorated. In some species of Anolis it is carmine, in others lemon yellow or banded crimson and burnt orange or apple green, the colors being singularly characteristic of each individual species. These belong to the males alone, for the females show but a trace of dewlap. It has been suggested that these brilliant colors attract insects and that the fanning out and closing of the appendage aids the display and that thus food is attracted where the lizard may easily spring upon it. This is not so. I have observed myriads of Anoles in places where they fairly swarm. Under the influence of genial warmth the male lizard stands high on his spindly legs, then squats, the while bobbing his head and opening and shutting his dainty fan (Fig. 83). It makes no difference whether female companions be near at hand or absent. The display reaction, once perhaps reserved for the time of mating, is now a natural recurrence whenever good health, pleasant weather, and abundant food combine to give complete satisfaction. Of all the devices for bodily beautification which we see in reptiles, none is more winning than this one. Its origin is in doubt, its purpose likewise, only a few allied forms give clues to the possible developmental stages passed through during the course of the fan's elaboration, but the end result is one of the fairest and most fascinating of the host of mysterious modifications which the reptilian body shows.

Sexual dichromatism. In some lizards males and females may be exactly similar in external appearance; this is the characteristic condition among skinks, anguids, and some other families. In others, again, there is great difference of form between male and female, and this is almost invariably accompanied by difference in color. This is particularly true of arboreal species, Iguanas, Anoles, and the like, but the African Agamas, which are by no means great climbers — except on rocks or roofs — have brilliantly painted males and soberly clad females. Writers have almost always stated that the male decoration was assumed at the mating season. This is, I think, never the case. The male coloration is a permanent character, most brilliantly shown just after the skin is shed and fading considerably before the next moult. There is usually a moult in spring at just about the breeding season or in the tropics with the incidence of the rains when many species mate; but the males are brilliant when moults take place at other times; hence I believe that in the Reptilia there is little or nothing which corresponds to the temporary male nuptial decoration seen in some newts, some fishes, and many birds.

CHAPTER XI

ADAPTATIONS OF FROGS

Amphibians, as a group, are of course older and more primitive than reptiles, but in some ways they have advanced farther than have their allies. In the matter of voice and in the care and protection of their young, the group shows a far greater plasticity than do reptiles.

Within certain definite limitations as to size and form the body of the tailless amphibians is subject to almost endless modification. The skin may be smooth and moist or dry with thickened derma, and with so-called warts scattered either indiscriminately or regularly. In general, frogs living in the water or in the moist woods have smooth slimy skins (Fig. 84), and the more or less xerophilous species have dry warty hides (Fig. 85), but there are many exceptions. The warts in most cases are glandular complexes through which irritant poisons — protective in their nature — are poured upon the skin. In many of the smooth-skinned forms the slimy exudate from the whole skin is highly poisonous. The nature of these poisons will be discussed later (p. 91). In some aquatic forms the skin becomes prickly, like shagreen, and this may also serve to give some protection.

Judged by external appearance many frogs and toads which anatomically are widely separated seem to be closely related. This becomes the more deceiving when specialization to some particular mode of life takes place. Thus our tree frogs (Figs. 86 and 87) in the Americas, some of which are so familiar, belong to a typically tree-living family, the Hylidæ, while in the Old World tree frogs

almost exactly similar in appearance (Fig. 88) are far more closely related to our common pond frogs of another family, the Ranidæ. Yet this parallelism of appearance is accompanied by a surprising similarity in the design and tonality of coloration, in the abdominal suction disk, in the dilatations (also for suctorial purposes) of the tips of the fingers and toes, and even in coloration and pupil form of the eyes. In the East Indies toads of the very same genus as our common New England garden toad have essayed arboreal life, and here again to a considerable extent the same peculiar modifications appear.

Frogs which have become completely aquatic (Fig. 89), seldom or never leaving the water, may lose or reduce the tongue, since there are now no insects to snap up. The teeth may be lost also, and the form may become compact and much depressed in cases where active prey is pursued, or they may become baggy, flaccid creatures with reduced bony deposits and with such ill-knit frames that they are helpless on land. Such are the curious and little-known frogs (Fig. 92) of the deep Andean lakes, Titicaca, Junin, and Jauja Paca. Alexander Agassiz in 1874 dredged frogs in eleven fathoms of water in Lake Titicaca and later found the same great sprawling beasts creeping at night about the reed beds near the shores. In 1909 the author tried to find these, but, possibly on account of the unusually icy weather, was unsuccessful. In the small streams and about the springs on the hills around the lake occurs a perfectly normal-appearing frog (Fig. 91), but certain definite peculiarities make it almost certain that it is this very frog which, going into the lake and assuming a wholly aquatic mode of life, has given rise to the curious big flabby *Telmatobius culeus*. That this is true is rendered the more probable by the fact that about the northern lakes, Junin

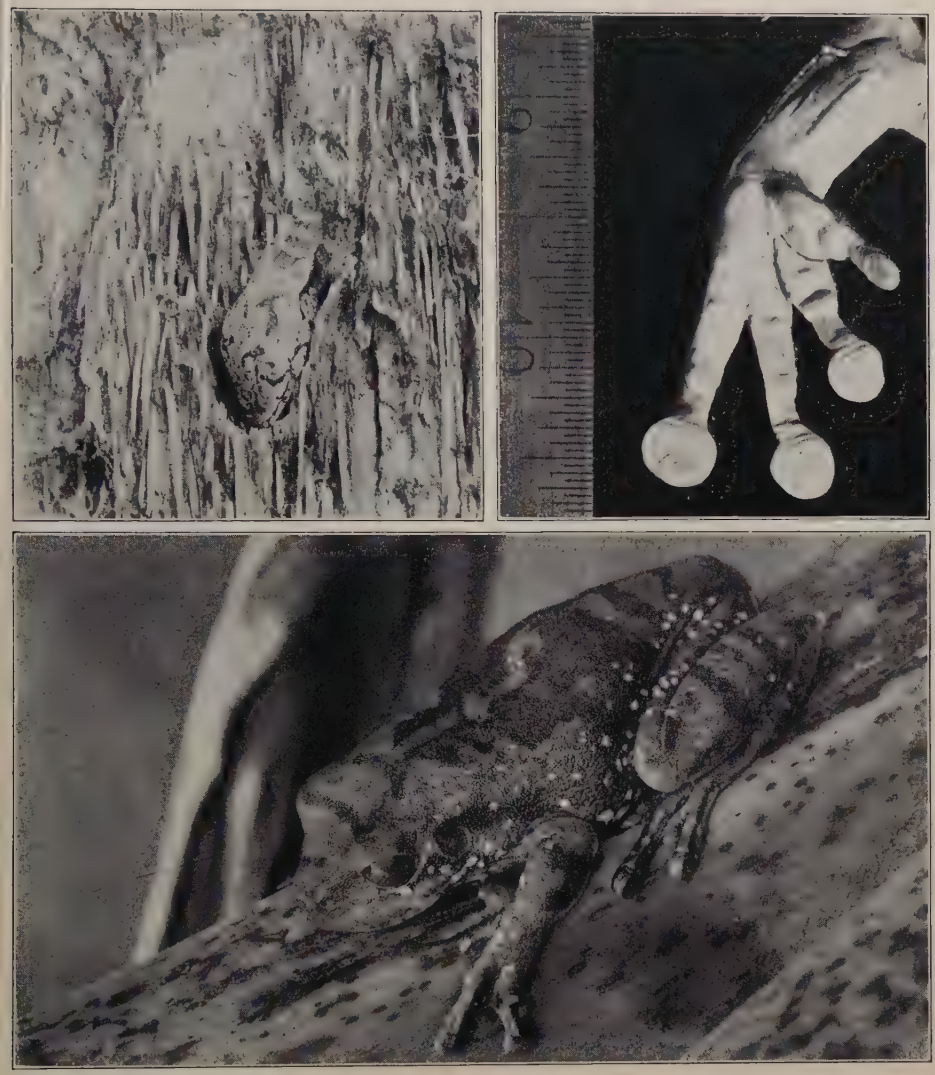


FIG. 86. THE FLORIDIAN HYLA SQUIRELLA, ON A CYPRESS TREE TRUNK

A tree frog showing remarkable protective coloration.

FIG. 87. THE HAND OF HYLA INFRAFRENATA, FROM TERNATE IN THE MOLUCCAS

Showing sucking discs to enable the tree frog to climb smooth surfaces. This species often clings to banana leaves. It is brilliant green.

FIG. 88. HYLAMBATES

One of several African tree frogs which superficially resemble greatly some American, or hylid, tree frogs, although really of ranid, or pond frog, ancestry.

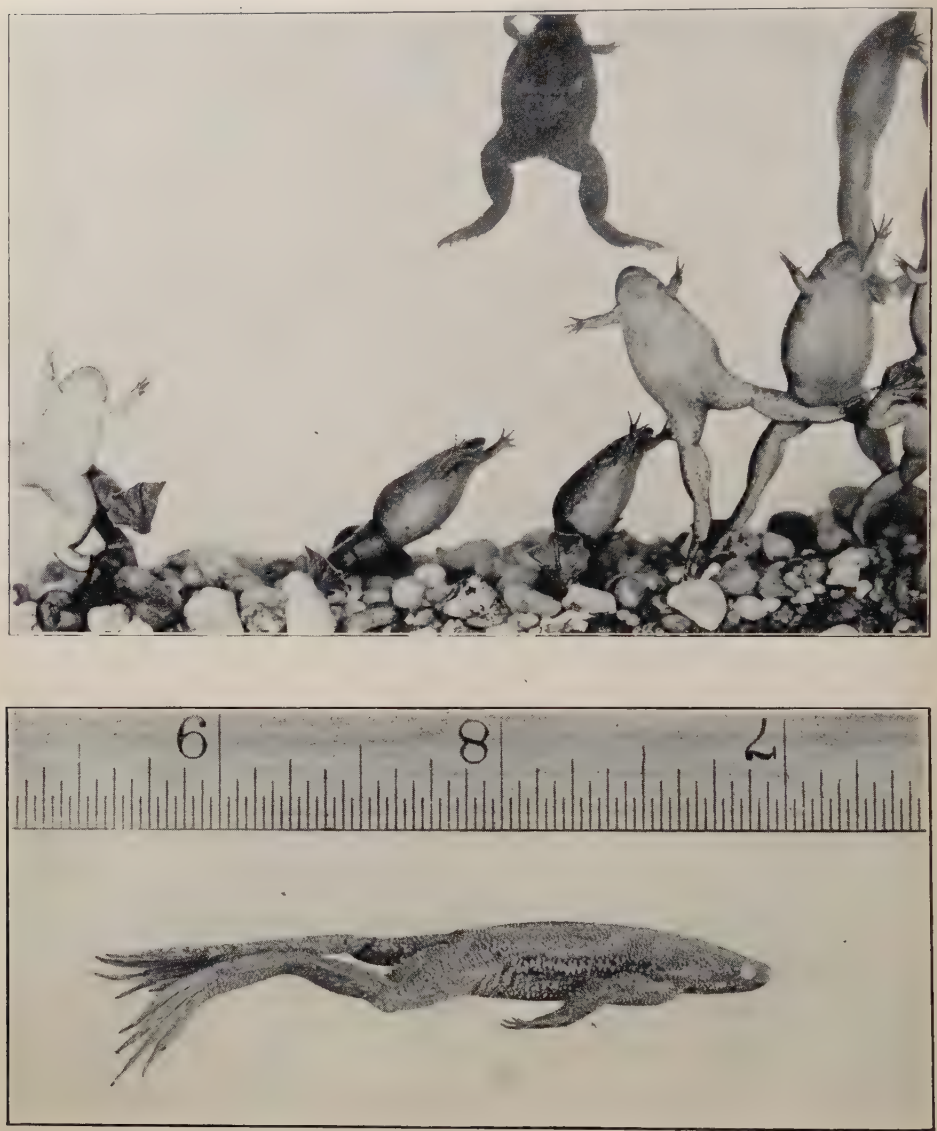


FIG. 89. SMOOTH CLAWED FROGS (XENOPUS) OF AFRICA

They are very strictly aquatic. This is shown by the enormously webbed hind feet, and the weak slender fingers, which have assumed an exaggerated tactile function since they play no part in locomotion.

FIG. 90. HYMENOCHIRUS FROM WEST AFRICA

A much depressed type well adapted for active wholly aquatic life. Both fingers and toes are webbed.

and Jauja, a typical frog occurs in the moist places along streams, while in the deep icy lakes another but quite different great flabby frog appears which has gone even farther than its Titicaca relative, in that it has become quite toothless. This frog is *Telmatobius microphthalmus* [1] (Fig. 93).

These Andean frogs come rarely to the surface; indeed recent observations tend to show that they never come up to breathe. It is not, therefore, improbable that the great flaps of loose tissue and the baggy form have been acquired for the purpose of increasing the superficial area of the body, since respiration is obviously not carried on by the lungs, but instead the skin must perform this function. Since these frogs live creeping about on the bottom of the lakes and beyond doubt feed on prey living in a similar situation, lungs would be an embarrassment tending to float them up; hence their lessened development and the substitution of dermal for pulmonary respiration. This is in line with what Dunn and Wilder have postulated concerning the origin of certain salamanders. It has long been known that some of these lack all trace of a lung and that many of them live in swiftly running mountain brooks. Nevertheless, all lungless species are not confined to this sort of habitat. It is very probable, however, that every type that lost its lungs evolved in a mountain-brook habitat where lungs were disadvantageous hydrostatically and hence were lost through lack of use as the creatures breathed less and less in their efforts to hold to the bottom and to prevent being floated away to the larger waters where they would fail to survive. The probability that

[1] Some naturalists use Batrachophrynus as a generic name for this species believing that the absent teeth warrant separation from Telmatobius, but the line here is very tenuous.

lunglessness arose through this type of evolutionary activation is so strong as to amount almost to certainty.

Before these biological relationships were pointed out in a work written in collaboration with the author's gifted former associate, Dr. G. K. Noble, the Lake Junin frog was called *Batrachophrynus microphthalmus* (Fig. 93), while the two land forms and the Titicaca frog were all placed in the genus Telmatobius. For in these contrasting forms the presence or absence of teeth was considered, naturally enough, a character of great apparent import, whereas it is really of no significance at all, for teeth may be lost or retained in species or genera that are very closely allied. This discovery, first pointed out by Van Kampen, of Amsterdam, while studying East Indian island species, and elaborated by others, has profoundly modified the accepted systems of amphibian classification during the last few years. In some cases, this character may be of generic value; in other cases it does not seem to be so.[1]

Only a very few other groups of wholly aquatic frogs are known: the Pipas of South America, which carry and hatch their young in cavities in the back, as will be described later (p. 87); and the African genera, Xenopus[2] (Fig. 89), Hymenochirus (Fig. 90), and Pseudhymenochirus, all rather similar in form to Pipa, if not actually related genetically. Life is evidently passed by these forms in shallow stagnant water, with frequent trips to the surface

[1] Dr. Noble (Bull. Amer. Mus. Nat. Hist., 46, 1922, pp. 1–87) has proposed a new classification of the Salientia or Jumping Amphibia. It is scholarly, suggestive, and often convincing, and while the author has already revised some of his conclusions, advisedly, nevertheless this paper is one of the most important which has appeared in some years.

[2] Often called 'clawed frogs,' with good reason. Excessively few Amphibia have developed claws. One Japanese salamander, Onychodactylus, has them well grown.

FIG. 91. TELMATOBIUS ÆMARICUS FROM ANDEAN STREAMS NEAR LAKE TITICACA
This is beyond doubt the direct ancestor of *T. culeus*.

FIG. 92. THE MUCH LARGER AND BIZARRE-LOOKING TELMATOBIUS CULEUS FROM THE DEEP WATER OF LAKE TITICACA ITSELF
This frog is modified for inactive aquatic life.

FIG. 93. TELMATOBIUS MICROPHTHALMUS, OFTEN CALLED BATRACHOPHRYNUS, FROM THE HIGH, COLD LAKE JUNIN IN THE PERUVIAN ANDES

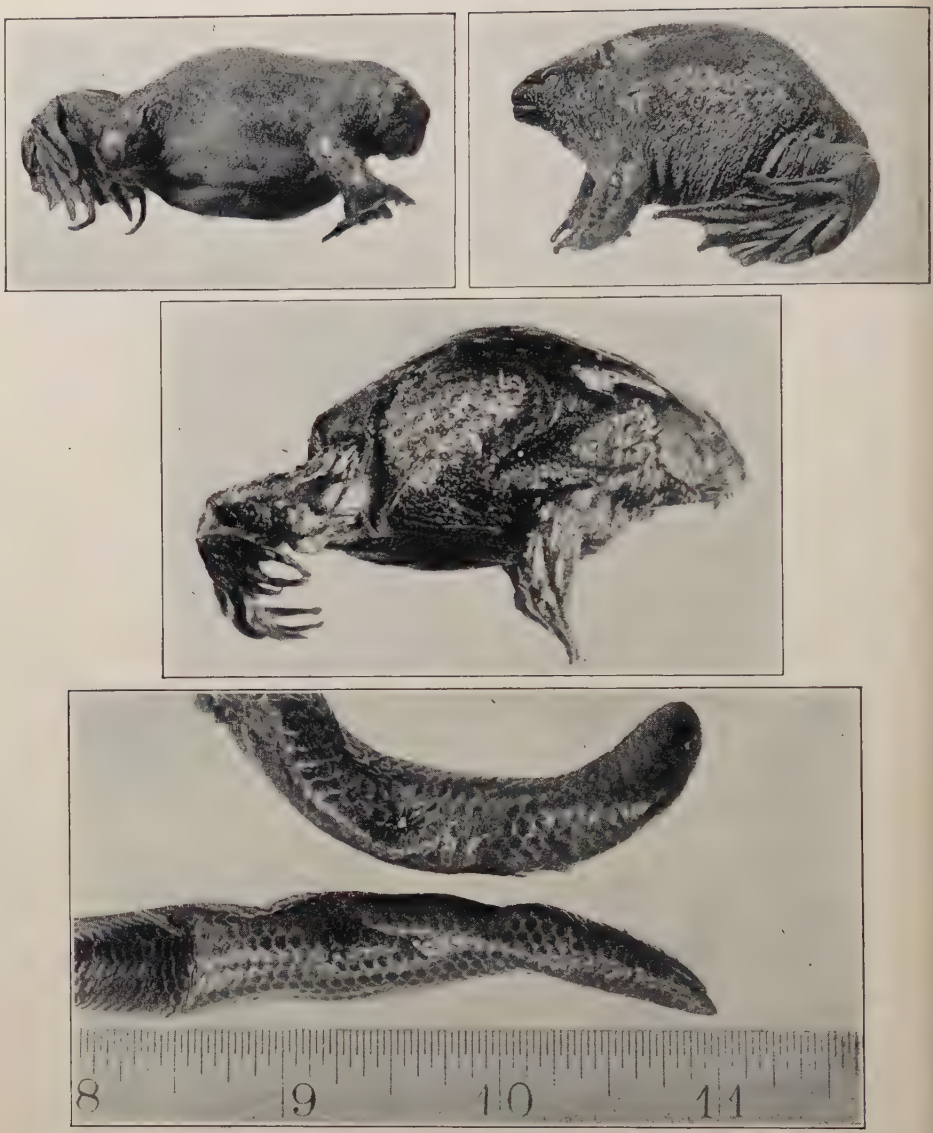


FIG. 94. GLYPHOGLOSSUS FROM SIAM; FIG. 95. RHINOPHRYNUS FROM MEXICO; AND FIG. 96. RHOMBOPHRYNE FROM MADAGASCAR

Three very distantly related genera of amphibians, all of which show great similarity of form one to another, and all three living wholly upon ants.

FIG. 97. A UROPELTID SNAKE FROM INDIA

The head is sharp for burrowing, the tail blunt and with a horny shield which completely stops up the burrow.

for breath. The powerful hind limbs indicate that the prey of all these frogs may at times be followed up swiftly and then gulped down after the fashion of many fish.

Another habit of life which has been accompanied by great change of form, either as cause or as effect, is the burrowing habit resulting from myrmecophagy. Termites and ants form a rich and adequate diet if they can be obtained in quantity. The great tropical colonies of these insects seldom move and they increase and multiply with great rapidity. Thus ant-eating toads (Figs. 94–96), which live in close association with the colonies, become almost parasitic; the mouth becomes much narrowed, the nose becomes long and pointed, the eye degenerates, the external auditory apparatus — the exposed eardrum — disappears, and the small weak fore limbs can hardly support the great obese body. The hind limbs retain some strength and are provided with a more than usually well-developed shovel-like tubercle on the heel which aids in digging. For, indeed, these toads invade the very termitarium or ants' nest, and, ensconced in some little cavern near a gallery where the insects pass and repass, live a colorless if gastronomically satisfying existence. The similarity in appearance of these distantly related ant-eating toads in Mexico, Costa Rica, Siam, India, Madagascar, and the Congo is very great.

Phragmosis. Frogs and toads sometimes make a curious use of their heads. It is well known that in many frogs the skin of the head becomes involved in the cranial ossification and becomes adherent, indurated, and rugose. This makes a hard bony head, and should the frog back into a burrow it has but to tip this head down to close the entrance effectively. That this was ever regularly done on a large scale was never known until by chance, the author,

after many long hunts for *Bufo empusus* in Cuba, chanced upon an open field over which were scattered many small burrows. These were evidently of two sorts, for the openings of some were carefully rimmed with smooth patted clay, while the others were rough and looked unfinished. Each of those with the rims contained one of the toads for which he had searched so long — the *sapo de concha* in Spanish — the shell-headed toad. These tube-like burrows were perfectly cylindrical and perhaps seven to ten inches deep. The toad, which always looked larger than the burrow, when it was removed, was to be found near the bottom of the hole, the horn-like head forming a perfect operculum and perfectly fitting the caliber of the tube (Fig. 98). The rimless burrows each contained a tarantula.

Later I learned that Professor W. M. Wheeler had become interested in cases where parts of insects were modified to stop a hole for protection. This process he has called 'phragmosis,' and the modified species 'phragmotic,' from *phragma*, a partition or septum. There are other phragmotic Amphibia beside the Cuban *sapo de concha*, other toads and some tree frogs in which the head is curiously and elaborately expanded, beyond doubt for this same purpose, to judge by the attitude assumed after death, with the head tipped down, as seen in preserved specimens. Tree frogs of several genera (Fig. 99) modified in this way are to be found on the west coast of Mexico, in Yucatan, and in Brazil. There is also a group of phragmotic snakes, the Uropeltidæ (Fig. 97), where the head is sharp and the tail knobbed and shielded or even sometimes roughened on the phragmotic surface. Perhaps the most marvelous example of all is to be seen among mammals, in the two species of Pichiciegos of Bolivia and northwestern Argentine. These little armadillos of the genus Chlamy-

FIG. 98. BUFO EMPUSUS OF CUBA

It lives in a burrow for which its hard, shelly head forms a perfect stopper.

FIG. 99. IT IS PROBABLE THAT TREE FROGS LIKE TRIPRION, CORYTHOMANTIS, AND PTERNOHYLA USE THEIR CURIOUSLY MODIFIED AND EXPANDED SHELL-LIKE HEADS FOR SOME SUCH PURPOSE AS THIS

FIG. 100. PSEUDIS OF SOUTH AMERICA

A sketch (after Garman) showing possible use of the opposable thumb.

FIG. 101. TADPOLE AND ADULT OF PSEUDIS

Here the larva shrinks in metamorphosis and the adult frog is smaller.

FIG. 103. ASTYLOSTERNUS, THE SO-CALLED HAIRY FROG OF CAMEROONS

The function of the cutaneous glandular filaments has been variously interpreted. Needless to say, they bear no relation to hairs.

dophorus burrow and live underground. Their body is nearly cylindrical, the head sharp and pointed, and the great fore limbs are mole-like in the extreme, but the posterior end of the body is as if sharply chopped off and is covered by a bony shield. This closes the burrow perfectly and no prying snake following its underground path could possibly get its jaws about it. This is the most perfect example of phragmosis which can be found.

Professor Shaler used to say that the development of the opposable thumb by some anthropoid ancestor was probably the most important single step toward the ultimate appearance of man. However this may be, opposable thumbs have been acquired by several genera of amphibians. In Pseudis (Figs. 100 and 101), well called the 'paradoxical frog,' this type of hand is to be seen, and we may perhaps postulate its use in grasping water plants for support. In this genus the tadpole stage is long and a large size is attained, far larger than that finally assumed by the adult form. This led in earlier times to the belief that here was a connecting link between frogs and fishes, and the creature was named Batrachichthys, for the big fish-like tadpole was supposed to be the adult form, derived from the little frog.

Bare bone is seldom seen under normal conditions in Nature. Yet in a few genera of frogs in Africa and in a few species in the Riu Kiu Archipelago and Formosa the bone of the thumb pierces the skin (Fig. 102), and this, coupled with a powerfully developed forearm, makes not only a formidable defense, but a useful assistance in securing and cracking the prey which in the case of one of these 'dagger frogs' is fresh-water crabs.

Another remarkable species has been called the 'hairy frog' (Fig. 103). This curious creature is confined to a

restricted area of Southern Cameroons, where the adult males develop a curious growth of fine glandular filaments or 'hair.' The use of this growth is not known, although Kükenthal demonstrated nervous tissue in sections of these filaments, which perhaps suggests a sensory function. Bashford Dean has suggested that they possibly may help to entangle strings of eggs and so aid the parent in keeping them near her.[1] A European frog, *Alytes obstetricans*, carries the eggs in strings wrapped about the thighs.

FIG. 102. THE TIP OF THE THUMB OF A DAGGER FROG, GAMPSOSTEONYX OF WEST AFRICA, SHOWING HOW THE BONE ITSELF PROTRUDES THROUGH THE TISSUES

Most of the families of frogs have produced terrestrial, arboreal, aquatic, or burrowing species. Their bodily form has become modified and their environment is perhaps still shaping various organs, principally, of course, those by means of which the animals come most directly into contact with their surroundings. Such are adhesive disks, dentition, general habit of body, length of limb, wartiness of the skin, presence or loss of tympanic disk. These are the chief so-called adaptive characters, although habits, use, or disuse may influence and ultimately change, even if indirectly as perhaps through selection, almost every other organ, as the tympanic cavity, Eustachian tubes, vertebræ, ribs, coccyx, or pectoral arch. There are tree toads

[1] Much more recently Dr. Noble feels sure that the 'hairs' serve a respiratory function. He makes out an excellent case to support his view. The only argument against this view is that for such an important function they are rather erratically developed. Females and young males lack 'hairs' and in the adult males the degree of development seems to vary. The breeding female would probably need the greatest supply of oxygen.

of the family Bufonidæ, which are as smooth, wartless, slender-bodied, and long-legged as the most typical of 'frogs'; again, there are true Ranidæ, like Hylambates in Africa, or the species of Polypedates in Asia, which, by their vivid colors, large adhesive disks, and arboreal habits, may well put any of the Hylid tree frogs to shame.

Nesting habits of frogs and toads. Every one is familiar with the appearance of our toads and frogs at earliest dawn of spring. They come trilling joyously to the ponds and streams, there to lay their eggs singly or in strings or clusters; thereafter the adults retire to their wonted solitudes and in due season the eggs hatch to tadpoles. These fish-like larvæ (Fig. 104) show many peculiar adaptations which of course bear no relation to the adult conditions, for the course of evolution in adult and larva runs quite independently and many frogs closely allied and very similar as adults have widely differing tadpoles.[1] Thus, in one species of Megalophrys in Java the little pollywogs (Fig. 104, central figures) have curious lip-like fimbriations about the mouth like an outblown umbrella, and by means of these strange lips the larvæ hang suspended from the surface film of the water. Others are brilliantly colored with wide, gorgeous fins; still others have disks allowing them to fasten by suction to rocks and stones, as do some of the South American Siluroid and Loricariid fishes.

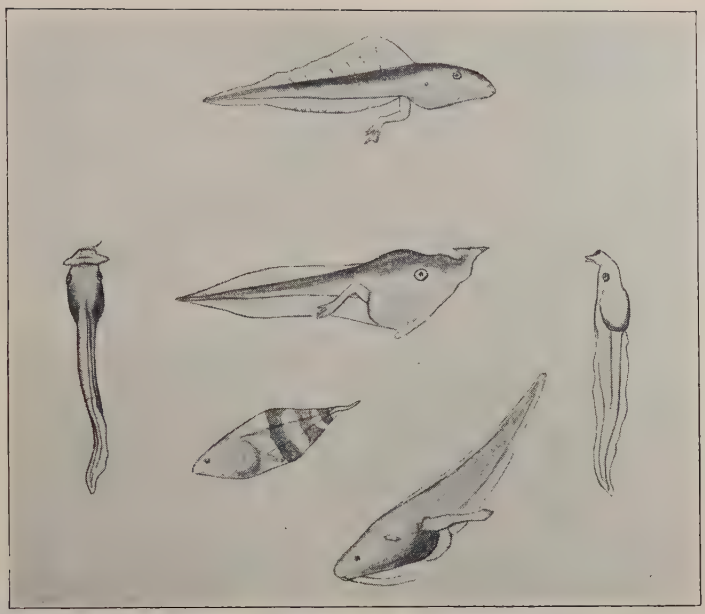
This life-history of egg and tadpole, gradually transforming to the adult by the sprouting of limbs and the absorption of the tail, constitutes what we may call the normal life-history, the most usual one when the number of eggs laid is very high and the infant mortality very

[1] Dr. Noble has recently shown that certain larval characters may be correlated with the relationship of the adult. Dr. Dunn of Smith College, however, has recently found some striking examples of closely related adults with very different larvæ.

great. Many species, almost all of them inhabiting the tropics, have devised means of caring for the larvæ, and nest-building among Amphibia is little less varied in style and scarcely less ingenious than among birds. Two forms belonging to different families in South America, *Hyla faber*,[1] a tree frog of southern Brazil, and *Leptodactylus ocellatus*,[2] a common pond frog of the Argentine, dig up mud from the bottom of the pond to which they repair to breed and make little craters (Fig. 105), the rims reaching higher than the water level. In these pens the eggs are laid and the larvæ, which soon emerge, swim about in the little enclosures safely protected from predaceous fish and insects. These little ponds were first seen in the garden of Dr. Goeldi, a Swiss naturalist living in Brazil. He recorded them first in 1895.[3] Twelve years later, on the Island of Marajó at the mouth of the Amazon, some Indians told him of a frog that made a nest of vegetable pitch. This tree frog he finally found. It was a new Hyla, which he called *resinifictrix* (Fig. 106) from its habit of lining a cavity in a hollow tree with a thick layer of pitch, as Goeldi believed, this making the cavity hold water. In a depression in this gum the eggs were laid and the larvæ reared. Five years later, Dr. Lorenz Müller, of Munich, visited this locality and found that the material used was not pitch, but beeswax which the frog got from the large open combs of the stingless Meliponine bees to be found in nearly every hollow tree in the American tropics. This remarkable frog is so rare and so restricted in habitat that few persons, unfortunately, will ever have a chance to observe its curious habits.

[1] Of the family Hylidæ. [2] Of the family Leptodactylidæ.

[3] Very recently the same habit has been recorded for *Hyla rosenbergi* in Eastern Panama by Breder.



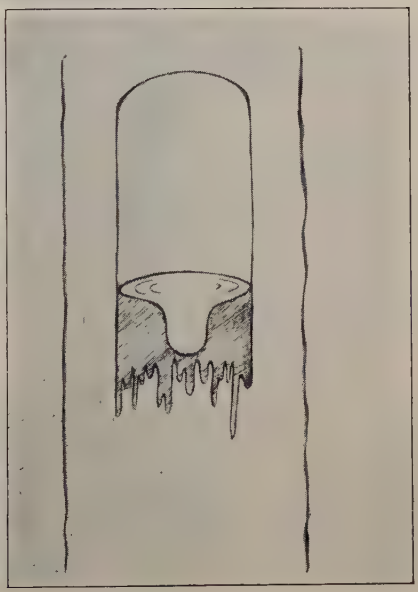


FIG. 104. SKETCHES TO SHOW VARIOUS FORMS OF TADPOLES
The three middle figures of *Megalophrys* show the curious fimbriated peristome.

FIG. 105. CRATER-LIKE NURSERIES OF THE BRAZILIAN TREE FROG HYLA FABER

FIG. 106. WAX-LINED NURSERY PUDDLE OF HYLA RESINIFICTRIX OF MARAJO ISLAND NEAR PARA, BRAZIL (*in section*)

FIGS. 107 AND 108. CHIROMANTIS, AN AFRICAN TREE-LIVING FROG AND ITS NEST

The secretion of slime, a characteristic of many Amphibia, has been seized upon in several unrelated groups to aid in egg protection. Slime produced at the time the eggs are laid is whipped up into a meringue-like froth and in this the eggs are placed. In 1909, the author observed in Jamaica that a common woodland frog (*Eleutherodactylus luteolus*)[1] laid its eggs in little nests dug out under logs or stones and filled with this froth. These eggs were usually about thirty in number, and one nest, in which the embryo could just be seen moving in the eggs, hatched young frogs in about two hundred hours. The tadpole stage was entirely suppressed, a phenomenon that we will consider later (p. 82). In Paraguay, in South America, *Leptodactylus mystacinus*, a common frog, lives a wholly terrestrial life as an adult, not entering the water at all. Its eggs are laid in froth in cavities near the river and stream banks; heavy freshets coincide with the breeding season and wash out the tadpoles which then transform in the open water. If, however, the rivers do not flood sufficiently to let the larvæ free, the latter remain in their moist nest huddled together in a compact mass and so await the next rainy season. Another Paraguayan frog (*Paludicola fuscomaculata*), peculiar in that the alternate inflation of both throat and abdomen produces a singular two-note call, lays its eggs in a floating island of froth in which the larvæ wriggle for eighteen to twenty-four hours before pushing out to hang suspended from the frothy float. The most unusual froth-producer, however, is the West African Chiromantis (Figs. 107 and 108). Here the froth is beaten up apparently by the fore limbs — at least this was observed once in the Congo by the explorer Lang — and the eggs are laid in the foaming mass that is placed

[1] Of the family Leptodactylidæ.

in the sun on a stick or a broad leaf. The surface then hardens and the young transform in a cocoon, as it were.

The Japanese tree frog, *Polypedates schlegeli*, has been very carefully watched by the Japanese naturalist Ikeda. Here the female beats up the froth with her hind legs, while the male, grasping her loins with his fore limbs, draws out the string of eggs with his own hind feet, fertilization taking place at this time as is usual with the *tailless* Amphibia. This process takes place in holes in moist soil and here the young transform in the foamy nest. Nelson Annandale, my old friend and the late Director of the Indian Museum at Calcutta, observed a Malayan species of the same genus, *P. leucomystax*, in which the life-history was essentially similar, so that these habits are probably much more widespread than is now known.

FIG. 109. THE NEST OF PHYLLOMEDUSA

Eggs are laid in a mass deposited between leaves which it gums together. Here no frothy 'nest' is made. In other species the eggs may be laid about on the surface of leaves, being stuck fast along the leaf-veins.

Some South American tree frogs, gorgeous green in color, fold up leaves and gum them together to make a

regular nest (Fig. 109) in which the eggs are laid, usually or always with an envelope of froth to preserve them from drying out, for drying is fatal to all young Amphibia and to adults that have a moist skin, so intimately is the integument associated with auxiliary respiration.

The various brilliant species of Phyllomedusa and Agalychnis draw together leaves in this way and the curious reader is referred to the scattered literature for further details. Regarding the Gebürtshilfer Kröte, or the 'midwife toad,' of Germany (*Alytes obstetricans*), in which the male carries the strings of eggs twisted around his legs, a most astounding mass of literature as well as much fable has gradually come into being. This European species has been conspicuous as practically the only one of these brooding frogs that occurs in the temperate zone.

CHAPTER XII

ADAPTATIONS OF FROGS (*continued*)

Abbreviated life-histories. The shortening of the duration of larval life is naturally desirable, especially in a species of small population, laying but few eggs. Budgett observed in Uruguay that *Phryniscus nigricans*,[1] a tiny black toad with flame-colored hands and feet, laying its eggs after the manner of our toads, had almost omitted the larval stage, so quickly did transformation take place, for eggs that were but segmenting at 10 A.M. showed tadpoles wriggling in the jelly-like egg capsule and almost ready to emerge by 7 o'clock of the next morning. *Hylambates brevirostris* (Fig. 110), of equatorial Africa gathers the new-laid eggs into its mouth and there, amply protected, they hatch as tiny adults, a unique case and an inconvenient method which must involve a temporary cessation of feeding on the part of the female. The wood toads of the genus Nectophryne (Fig. 111), common in Africa, have the oviducts enlarged and therein the eggs are retained and thence the perfect young emerge. It is noteworthy that this ovoviviparity, so often seen among reptiles, has hitherto been observed among Amphibia in this one genus only. All turtles and crocodilians lay eggs, as do most lizards, but with some of these and with many snakes, especially the vipers, the eggs are retained in the body until hatched when the young emerge and usually the egg cases are simply resorbed.

There has been, however, a large variety of substituted attainments to help protect the young, many far more

[1] Now called *Atelopus Stelzneri.*

FIG. 110. HYLAMBATES (OR LEPTOPELIS) AUBRYI, FROM THE CONGO

This is closely similar in appearance to *H. brevirostris* from Cameroons and Gaboon. The latter species hatches its eggs while holding them in its mouth.

FIG. 111. A COMMON WEST AFRICAN NECTOPHRYNE

Small toads of the genus *Nectophryne* are among the only Amphibia known where the eggs are hatched within the mother and the young are born alive, as in so many reptiles.

FIG. 112. DENDROBATES CARRYING ITS TADPOLES ON ITS BACK
Taken at Kartabo, British Guiana, by C. William Beebe

FIG. 113. RHINODERMA FROM CHILE WITH THE VOCAL SAC CUT OPEN TO SHOW THE YOUNG TADPOLES WITHIN

elaborate and with an evolutionary history vastly more difficult to postulate than this comparatively simple and effective ovoviviparity. For instance, the larvæ may be actually carried about by the parent. Thus, in the moist mountains of the Seychelles Islands a tiny species, *Arthroleptis seychellensis*, carries its little brood of tadpoles on its back to which they are attached by specially developed ventral suckers. In the rain forest of Central and South America several species of both Phyllobates and Dendrobates (Fig. 112) may be observed to carry their tadpoles about stuck fast to the dorsal skin by their sucker-like mouths. This is often to be seen and was first observed by Dr. Jeffries Wyman on his trip to Surinam about 1859. Strangely enough, if the young tadpoles are shaken off from the mother into a pool of water, they are said to be completely helpless.

The simple laying of the eggs in some protected place where they hatch directly without passing through a larval stage at all, is perhaps the most common as well as the oldest known of any of these peculiar syncopated life-histories. Dr. Bello y Espinosa first observed and noted this condition in Porto Rico, where later Gundlach confirmed the classic observation. Bavay, a French colonial surgeon, observed in Guadeloupe in 1873 that '*Hylodes*' [*Eleutherodactylus*] *martinicensis* emerges from the egg on the tenth day. On the ninth the tail disappears. Bavay reports ephemeral gills, which, according to his observation, are simply vascular bows, situated one on each side near the heart; these disappear on the seventh day. Stejneger, again, reported upon the Porto Rican *Eleutherodactylus auriculatus* in 1900. He wrote: 'The eggs are usually deposited in the damp axils of an air plant about twenty or thirty in a lump. The development of the young

is remarkable, for the anterior and posterior limbs appear simultaneously and there is no trace of gills.' As a matter of fact, the thin and highly vascular tail serves as a gill.

Guppy, who explored the Solomon Islands in 1883–84, wrote: 'During a descent of one of the peaks of Faro Island I stopped at a stream some four hundred feet above the sea, where my native boys collected from the moist crevices of the rocks close to the water a number of gelatinous balls rather smaller than a marble. Each of the balls contained a young frog (*Rana opisthodon*), with long hind legs and short fore legs, without tail, and bearing on the body small tufts of what seemed to be branchiæ. On my rupturing the ball or egg in which the little animal was doubled up, the tiny frog took a marvelous leap into its existence and disappeared.' This was a Rana and one not so very distantly related to our own bullfrog. The branchiæ Guppy speaks of were later found to be plications or lamellæ of the skin of the belly. It has been thought that the use of these was to increase the absorbing surface and thus promote respiration. Dr. Noble denies this, having studied some similar forms and concludes that the plications result from the folding of the embryonic body wall which accompanies the rapid absorption of yolk just before hatching.

Further exploration shows the probability that most, if not all, of the Amphibia in Papua, the New Britain and Solomon Archipelagoes, and in Fiji omit the larval period in this way. Only recently Dr. Mann, then of Harvard University, brought back data from Fiji making this very evident. The same condition obtains to some extent in the Antilles. Van Kampen has attempted an explanation for this. To survive in tropical regions, upon mountainous islands especially and where there are no ponds or slowly

moving streams and where torrential downpours of rain occur frequently, perhaps even daily, some mechanism is necessary whereby the larvæ will not be exposed to freshets and carried to sea. When these islands were connected with larger land masses in past geological time, appearing then as long mountainous ridges not as yet cut into archipelagoes, the Amphibia which migrated into these regions, and which survived, either had already become adapted to this sort of life-history, or else had promptly to acquire it in order to persist under the physiographic conditions obtaining.

It has very recently been shown that one of the most generalized and primitive frogs in the world (*Liopelma hochstetteri* Fitz) of New Zealand is like the other varied and unrelated types of frogs of the Solomon Islands and Fiji, indeed of Papuasia generally, in having a so-called direct development. The reasons for skipping the free-swimming stage when conditions do not favor the survival of tadpoles has already been discussed, but that this should be done by Liopelma in just about the same way that it is done by a Rana in the Solomon Islands and by other genera in Melanesia and in tropical America is very significant, and would seem to show that this latent tendency is a common widespread character inherent in all frogs from the most primitive to the most specialized, and that the environmental condition making direct development desirable is the only activator necessary to bring about complete suppression of the larval stage.

In the moist woods of the beech forests in southern Chile a tiny cricket-like frog called *Rhinoderma darwini* (Fig. 113) is found, a singularly alert and active little species. In this wonderful little creature the male takes the fertilized eggs and crams them down into his singing pouch,

which in the breeding season becomes greatly enlarged, even spreading over the belly, and herein they transform, to hop forth later from their father's mouth as fully developed froglets. Compare this with the case of *Hylambates brevirostris*, mentioned on p. 82.

The most famous, however, of all brooding devices is that of the Surinam toad. Even before the time of Linnæus, specimens of this strange creature had reached the cabinet of Seba in Amsterdam, and for a hundred years writers speculated as to how it was that the young came out of hollow cavities in the parent's back. It was not until 1896 that Mr. A. D. Bartlett, the late veteran Director of the London Zoölogical Garden, noticed that two males in a tank with several females were noisy and active. Finally the males were observed to grasp two of the females, clutching at their loins. One morning the keeper observed the mysterious oviposition. The oviduct of the female protruded over an inch, and this bladder-like protrusion was retroverted and passed back under the belly of the clasping male and pushed out and up upon the back of the female. The male pressed upon this bag and worked it from side to side, forcing the eggs out one by one, until they were spread uniformly over the female's back. It is probable that the spermatozoa had already been gathered by the extended oviduct and that the eggs were laid in a fertilized state, as in the newts. These eggs are pressed into the skin and finally come to lie each in a deep cavity which is closed by a phragma or lid, the origin of which is very uncertain. The cavities are simply pouches of the skin and are not formed by enlarged glands as some anatomists have suggested. Each cavity consists of the invaginated epidermal pouch and a lid. According to Wyman, the lid looks like a shiny or sticky layer which has hardened

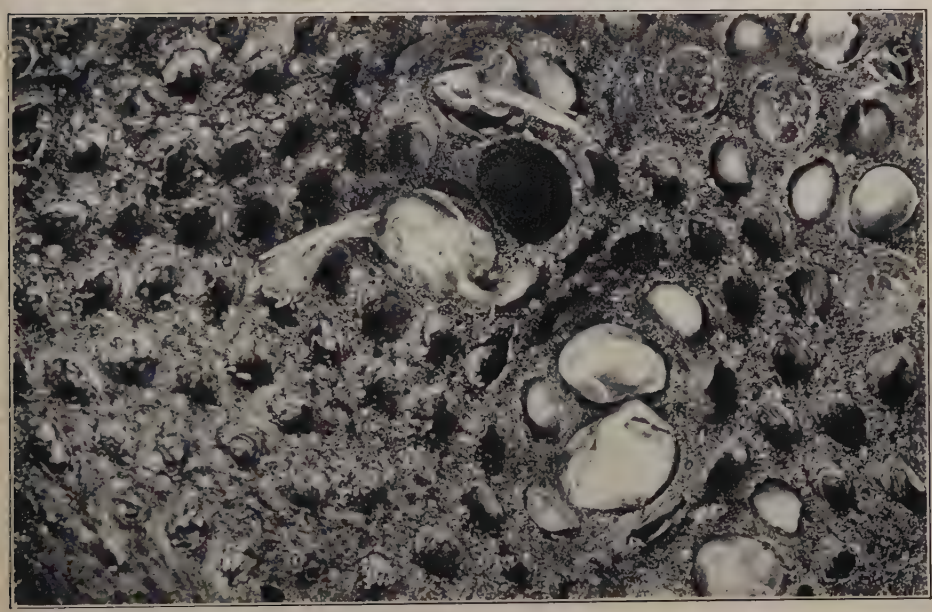


FIG. 114. PIPA, THE SURINAM TOAD; VIEW TO SHOW ADAPTATION FOR WHOLLY AQUATIC LIFE. ENORMOUS FEET, TACTILE FINGERS, WIDE MOUTH, AND MUCH DEPRESSED BODY

FIG. 115. SKIN OF BACK, ENLARGED, SHOWING VACUITIES VACATED, OTHERS WITH YOUNG FROGS JUST EMERGING, WHILE THREE SHOW THE CAP, CLOSING THESE CAVITIES DURING THE PERIOD OF HATCHING, STILL IN PLACE

FIG. 116. HYLA EVANSI OF BRITISH GUIANA WITH ITS EGGS

FIG. 117. HYLA GOELDII FROM BRAZIL WITH EGGS IN A SUPPORTING FOLD OF SKIN
This may represent the first step toward the formation of a dorsal brood pouch.

FIG. 118. A YOUNG INDIVIDUAL TAKEN FROM THE POUCH OF GASTROTHECA CORNUTUM, AFTER IT HAS HATCHED THERE AND DEVELOPED THE WINEGLASS-LIKE GILLS WHICH HAVE ALSO BEEN DESCRIBED IN AMPHIGNATHODON

FIG. 119. THE DORSAL POUCH (CUT INTO) OF A MARSUPIAL FROG (GASTROTHECA MONTICOLA) OPENED TO SHOW THE EGGS WITHIN
This genus *Gastrotheca*, named under a misapprehension but forced into use by the 'law of priority,' is generally called *Nototrema* in the older works on herpetology.

into horn-like consistency. It lies exactly like a cover upon the rim of the pouch itself, and is certainly not in structural or organic continuity with the epidermis. Most probably it is produced by the remnant of the eggshell itself, which, after the larva is hatched, is cast up to the top of the cup. Here within these cavities complete metamorphosis takes place, and in the figure the young may be seen emerging. This beautiful specimen (Figs. 114 and 115) was collected three quarters of a century ago by Dr. Jeffries Wyman in Surinam or given him by his friend Dr. F. W. Cragin for years American Consul in Paramaribo. Now several small species of Pipa are known in the Guianas, Venezuela, and Brazil, and the classic *Pipa pipa* of Surinam is found to have a wide distribution through the Guianas and Trinidad as well as in Amazonian Brazil. No other frogs brood their young after this manner, but other frogs carry their eggs upon their backs.

So far as we know, but one type, a species of Polypedates or Rhacophorus — a tree frog from Ceylon — has essayed the transportation of eggs by carrying them stuck fast to, even pushed into, the skin of the belly. This method is far less worthy of survival than the practice of carrying eggs on the back, a habit that has been picked up with varying and progressive elaboration by many members of the family of Hylidæ, Cystignathidæ, and Amphignathodontidæ. *Hyla evansi* (Fig. 116), from British Guiana, and *Cryptobatrachus fuhrmannii* of Colombia, simply carry the eggs stuck to the skin of the back, where they merely form little hexagonal depressions, which, however, in a way foreshadow the deep pockets in Pipa. *Hyla goeldii* (Fig. 117), from southern Brazil, has the skin of the back, around the area on which the eggs lie, closely compacted, raised into a rim-like supporting fold to keep

the eggs from falling off. So far as known, the eggs in these species are carried about until the young tadpoles emerge and leave the mother at some favorable opportunity while she is in a pool of water.

In the astonishing genus of horned tree frogs in the allied family Leptodactylidæ of Ecuador, a far more advanced state of affairs is to be found. Jimenez de la Espada described a number of species of what he called Cerathyla, but none of them happened to be carrying eggs. In 1903, however, a professional butterfly hunter, Ockenden by name, sent to Boulenger a horned tree frog carrying only nine large eggs (note that our common toad lays from 2000 to 6000 eggs and affords them no protection), each containing a little frog distinctly visible through the transparent and very thin egg capsule. These little frogs, their abdomens puffed out with the included yolk, lie belly down on the back of the mother with their limbs characteristically folded but showing also the following remarkable development: on each side of the gill-slit region two long strings appear, ending with bell-shaped or cup-like organs, which, being closely applied to the thin and highly vascular dorsal integument of the mother, serve beyond doubt to assist in some transfer of nourishment. Here, be it noted, the developing eggs lie open and unprotected, while the young undergo the entire development attached to the mother, after which the much-thinned and depigmented skin of her back, to which the eggs have adhered, is sloughed off. Now the two Hylas we have mentioned belong to one series within a single family, while Cerathyla for valid reasons should be placed in another family, the Bufonidæ as defined by Noble or the family Leptodactylidæ which most naturalists still prefer to recognize as a distinct entity.

The next stage and a great advance in the method of egg protection is to be seen in the complete formation of a dorsal pouch for the brooding of the young (Figs. 118 and 119). This has been developed both in the Hylids (being recorded in Nototrema for a number of species) and in Amphignathodon, the type of a third well-defined family closely allied to the true tree toads or Hylas. In these the skin of the back begins to overfold antero-posteriorly until the lip of the discoidal fold reaches progressively farther and farther backward and finally puckers closely together (Fig. 89). The inner fold of the skin becomes thin, tenuous, and depigmented, as does also the under layer of the skin of the back. The edge of this fold remains closely applied, really fusing with the dorsal skin, until the eggs are laid and probably also between each breeding season, when the edge ruptures and a large open pouch, as shown in the figure, results. Into this pouch the eggs are probably pushed by the male, although of this there is no certain knowledge. In some species of the genus the eggs are kept in the pouch only a short time until the tadpoles emerge and take up independent aquatic life. In more species, however, bell-like outgrowths from the gills (Fig. 118), similar to and paralleling those described in the relatively unrelated Cerathyla, are developed to assist the young in obtaining nourishment from the parent, doubtless by osmosis, and in these species the young frogs emerge from the pouch fully formed. In this habit, as in the matter of developing the opposable thumb, the amphibians show that they have reached out and essayed various experiments in directions fully elaborated elsewhere by the higher mammals only, for this attempt to obtain nourishment from the parent, which apparently has led to no extraordinary success, is in a way analogous to

placentation and is something that has been tried also by the sharks, where the developing young are retained within the female and the yolk-sac becomes modified to form a pseudoplacenta.

We have seen that for purposes of protection many different types have arrived at similar methods of omitting the larval stage entirely, and again that when for various reasons it is undesirable to pass through such a stage the eggs, as of Hylambates, for instance, may be carried in the parent's mouth for protection, or even, as in case of Rhinoderma, in the enormously enlarged vocal sac extending from the throat far down the belly. Still, in none of these types is there any such elaborate mechanism for the sustenance and protection of the developing larva as is seen in the cases where the remarkable gill-like organs are developed in connection with modification of the skin of the adult. The most important lesson to be learned from this remarkable series of examples chosen to show progressive elaboration of structure and habit is that it has been necessary to select many forms genetically distantly related in order to demonstrate the stages of increasing complexity, and these are in no wise to be considered as bearing any serial relation one to another in phylogenetic descent.

Poisonous amphibians. Snakes are not the only venomous animals. There are many fish which have poisonous slime and spiny fin-rays or projecting bones with which to introduce poison. The male of the celebrated duck-bill or Australian Ornithorhynchus has a spine connected with a small poison sac on the inside of each heel, the function of which is quite mysterious. One lizard, Heloderma, is very venomous, as we have seen, and many marine invertebrates poison by means of nettle cells or nematocysts.

Most Amphibia secrete cutaneous poison of two sorts: a mucus, more or less like sweat in that it is generally secreted by small glands scattered over the whole body; and the so-called granular poison, a creamy exudate, purely for defense, derived from special differentiated areas. The mucous poison is a lubricant. It may easily be obtained by putting the animal in a retort containing normal salt solution and stimulating with a few drops of ether or chloroform. It may also be obtained by maceration of the skin. The mucus is not primitively a venom and in some forms it is harmless. In most cases, in both adults and larvæ, it is markedly toxic and possesses strongly hæmolytic as well as neurotoxic properties. Indeed, it is so similar to viper poison that a frog immunized against its own mucus is for a short time strongly resistant to viper venom.

The granular poison may be obtained by compressing the glands or so-called warts on the skin of the toad or by the nervous excitation of the animal causing the exudation of the poison; or it may be secured by excising the gland and dissolving out the poison with alcohol or ether. It is white, like the latex of milkweed, and when fresh it has a curious aromatic odor. It dries very quickly and then turns brown. The action of this poison is entirely different from that of the mucous sort. When introduced into the stomach it is a powerful irritant, causing almost instantly in a dog, for example, severe trembling, weakness of the legs, and nausea. A small quantity placed on the tongue causes profuse salivation and nausea, and death may follow if the dose be sufficiently large. Introduced into the blood stream, however, it is not fatal except in very large doses. It is also highly irritant to the cornea. This poison, of course, is a defensive development of the highest usefulness, while the fact that the mucus is toxic is without any

particular significance in all likelihood and is probably simply due to the same sort of fortuitous circumstances which give rise to toxins within the blood and which may or may not serve to immunize the individual against other poisons. One species, *Hyla vasta* (Fig. 120), of Santo Domingo, has a skin poison so strong that it burns one's hands painfully when the frog is handled. It is perhaps hardly necessary to say that toads cannot give warts even though their skin is poisonous.

Horned amphibians and reptiles. There is another curious somatic characteristic seen in many amphibians and reptiles, namely, the possession of horns over the eyes (mentioned on p. 51). Why these should be developed, it is impossible to understand. Desert species are especially prone to show them. They are prominent in the common desert rattlesnake called the sidewinder, but are seen, too, in Schlegel's Viper (Fig. 123), of the moist jungle of Central America. There are frogs, also, belonging to different families, that show this same curious development. Megalophrys (Fig. 124) illustrates this. The author found a number of these creatures living in the high mountains of central Java, and beyond the fact that the horns give to the animal a peculiarly alert expression they seem to serve no function whatever and probably again belong within the category of characteristics which Cope attributed to 'the superabundant growth force' of evolution, a series of ever-elaborating attributes or characters which are driven by some unknown impetus to increase to no useful end and which in some cases at least, may lead to the disappearance of the type through the development of some one characteristic to a positively detrimental degree.

Warning colors and postures. While most frogs when terrified at once take refuge in flight, a few forms, such as

FIG. 120. HYLA VASTA FROM THE ROCKY RAVINES OF SAN DOMINGO

A giant tree-toad, the skin of which secretes a slime which is actually caustic. This is a remarkable example of protective resemblance.

FIG. 121. BOMBINA, THE EUROPEAN FIRE-BELLIED TOAD, IN ATTITUDES OF WARNING

The soles of hands and feet are brilliantly colored.

FIG. 122. DENDROBATES TINCTORIUS, ONE OF THE MOST CONSPICUOUS, AS IT IS ONE OF THE MOST POISONOUS, FROGS IN THE WORLD

Specimen from Taboga Island, Panama.

FIG. 123. BOTHROPS SCHLEGELI, A CENTRAL AMERICAN TREE VIPER

It is strictly arboreal and the body and tail are strongly prehensile. The vertical pupil suggests nocturnal activity. The horns over the eye are of unknown significance. Bocas del Toro, Panama.

FIG. 124. MEGALOPHRYS NASUTA FROM BORNEO

the giant toads, simply hump themselves up and stay perfectly still, as if knowing that most animals are aware of their poisonous characteristics and evil taste. In many localities in the tropics where small crocodiles and predaceous fish abound, the startled frog, which has been lying in wait for insect prey along some stream, jumps back into the bush when frightened and does not dive into the water at all. This is almost universal in Florida, where young ''gators' await unwary frogs. Some forms, moreover, go through queer antics. Ceratophrys, the monstrous horned frog of the Pampas specially, opens wide its mouth and even jumps at an aggressor, inflicting painful nips, and looking, with its gaudy colors and its body all puffed up, like quite a terrifying creature. Some of the dagger frogs of the Loo Choo Islands can grasp a man's hand in their strong front legs and, by driving in the spurs on their thumbs, draw blood. Bombina (Fig. 121) turns up its bright-colored toes to give warning that it is a bitter mouthful, a warning, of course, that is really protective. One little frog, *Dendrobates tinctorius* (Fig. 122), coal black or rich maroon brown marked with metallic electric blue, is so poisonous that several tribes of tropical American Indians use it to poison their arrows. Another unrelated use to which this frog is put in Brazil is making artificially particolored parrots. If the parrot's green feathers are pulled out and the skin is rubbed with one of these toads, the feathers come in yellow when they grow again.

Many frogs of many different groups have most brilliant colors on the hinder side of the thigh, and these show only when the animal leaps. They are called flash colors, and whether or not they serve as a warning or protective device whereby one frog makes known to any chance neighbors that it has been forced to take a leap, is of course

purely conjectural. Nevertheless, there is probably some significance, were it understood, in connection with the widespread possession of these usually covered but very brilliant markings.

Death-feigning is another curiously developed habit. 'Playing 'possum' occurs all through the animal series. *Varanus exanthematicus* (Fig. 125), a lizard from the Congo, turns on its back and, seizing one of its paws in its mouth, lies perfectly still in this apparently uncomfortable position. Another classical example is the hog-nosed snake (Fig. 126), which turns over on its back, opens wide its mouth, hangs out its tongue, and looks as if it had just died in agony. The only mistake it makes, as we have said before, is that, if it is reversed, it promptly turns over on its back again. Our common toad and many others lie still when disturbed and assume any position in which they happen to be placed. The giant from the Congo (Figs. 128 and 129) is a case in point. Some snakes coil into a ball and remain quite motionless (Fig. 127), as has been previously stated.

Curiously enough, all individuals of a species do not act in the same way, although we are accustomed to think of reptiles and amphibians as creatures without much individuality.

Method of feeding in amphibians. The method whereby amphibians feed is pretty generally known. Frogs, with their tongue attached by its front end, flap it out and the small creature which serves as prey sticks to the tongue and is drawn back into the mouth. Many aquatic forms have lost the tongue altogether, an obvious example of loss by disuse. Some salamanders have tongues as elaborately contrived as those of the chamæleons. These are round, set on a stalk, and their similarity to a toadstool

FIG. 125. VARANUS EXANTHEMATICUS, AN AFRICAN MONITOR LIZARD
It assumes this curious pose when feigning death.

FIG. 126. HETERODON, THE SPREADING ADDER, FEIGNING DEATH
Note the protruding tongue.

FIG. 127. FLORIDA KING SNAKE COILING AS A MEANS OF PROTECTION
The head is inside the ball.

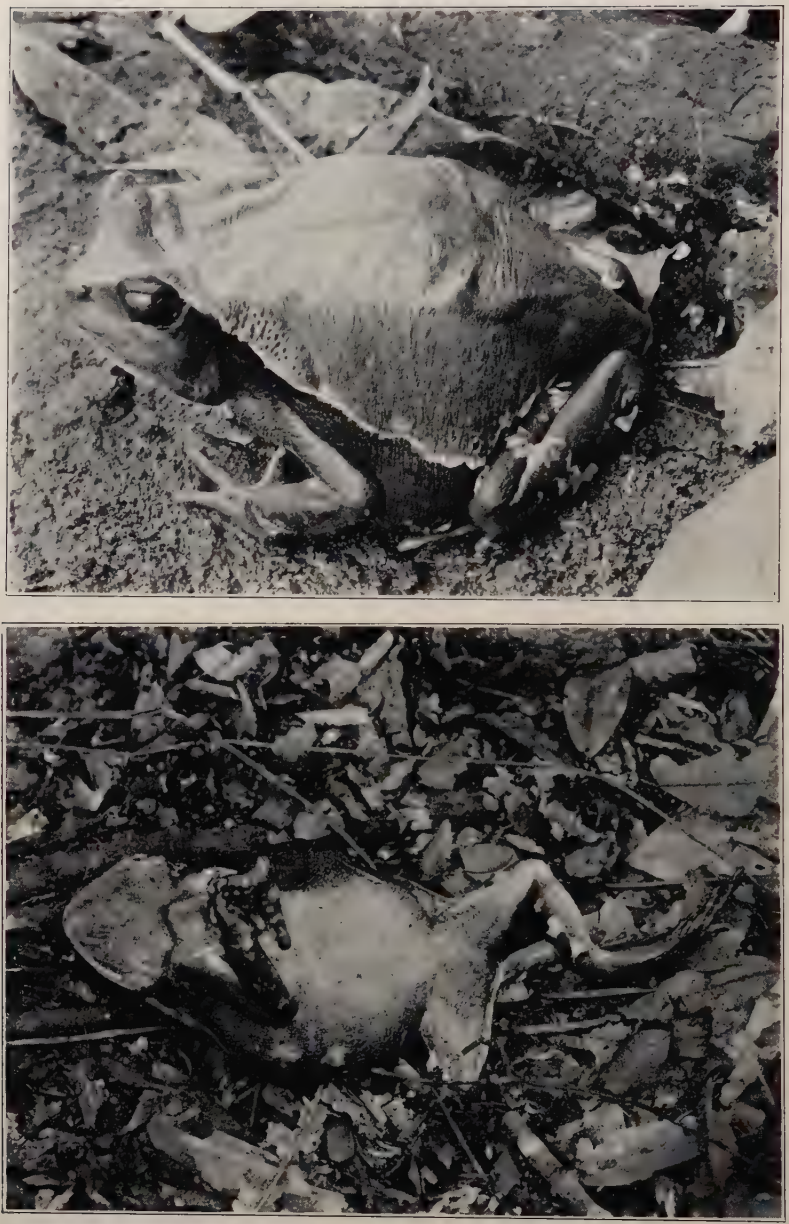


FIG. 128. LARGE FOREST TOAD FROM EQUATORIAL AFRICA (BUFO SUPERCILIARIS): ITS NORMAL APPEARANCE

FIG. 129. IN THE POSITION ASSUMED WHILE FEIGNING DEATH

gave the name Bolitoglossa to one group of species, although in these animals the stalk of the toadstool is extensile, allowing the tongue to be pushed far out and its sticky surface applied with precision to the insect prey.

Voices of amphibians. Amphibians are as vocal and voluble as reptiles are silent. The chorus that rises from our brook-sides and marshes in early spring is well known. Multiply this many times both in variety and intensity, and some conception may be had of the concert that greets the ear in some lonely camp in the tropical forest during the oncoming of the rains. At such a time frogs sing from under stones, from the ground, on grass stalks, in shrubs or tree-trunks, in the tree-tops, and even from under water. In the last case the air must be passed back and forth between the throat pouch and the lungs, time and time again.

I shall never forget one spring evening at Lake Okeechobee in the Florida Everglades. It was warm and still, a shower had just fallen, and the night was starry but dark. Suddenly such a chorus of frogs' voices began as I have never heard, many thousands of individuals making a perfectly ear-splitting racket. I got into my canoe and floated out into the reed beds silently and slowly. As I passed along I made a noiseless zone wherever I went, but by holding to a flag and keeping very still the chorus would soon be resumed. Once when this had happened, I flashed a strong electric torch — and to my surprise not a single frog was to be seen. I had expected to see swelling throats glistening in every direction. Astonished, I moved slowly along with my strong beam of light illuminating the water and reeds for a long way in every direction. Not a ripple was seen, as would have been observed had the frogs submerged when disturbed. I soon realized that I was present

at a great chorus where beyond a doubt the frogs were singing from beneath the surface of the shallow water.

Every one who has watched frogs in captivity knows that they never open their mouths during the ordinary singing, which is distinctly a nuptial development. Frogs can scream and do so with mouth widely agape. Our pond frog, when grasped by a snake, will open its mouth and shriek piteously, making a noise as startling as that of a rabbit or almost like a horse when painfully injured. I have heard this sound coming from underground so loud that, overcome with curiosity, I have dug down to find what was the matter. Once at Jupiter, Florida, it was a very large garter snake swallowing, hind legs first, a spotted frog nearly a foot underground in a rat's burrow. The sound could be plainly heard some distance off. When dug out, the snake let the frog go, but later pursued it in plain view in the open pine woods and again the frog opened its mouth and shrieked loudly. Some frogs do this when they are first caught. The gopher frog (*Rana æsopus*) will sometimes do so once, and so also the large tropical and nocturnal species of Leptodactylus, huge burrowing 'bullfrogs' unrelated to our familiar North American species of that name. Noble in Santo Domingo has named a species (*Eleutherodactylus inoptatus*), which I described some years ago, the 'barking frog.' This frog 'squeals like a pig' when handled. When Professor Cope named a related Texan form *Eleutherodactylus latrans*, he obviously knew of a similar habit.

FIG. 130. SCHLEGEL'S MAGNIFICENT FIGURE OF THE GIANT SALAMANDER FROM JAPAN, LEYDEN, 1833

FIG. 131. SIREN, WITH NO HIND LEGS AT ALL AND THE FORE LIMBS MUCH REDUCED

FIG. 132. AMPHIUMA, WITH ALL FOUR LIMBS PRESENT BUT VERY RUDIMENTARY

These two amphibians are found in rice-fields and muddy ditches throughout the coastal plain of the southeastern United States.

CHAPTER XIII

THE URODELES OR SALAMANDERS, AND THE CÆCILIANS

Urodeles. The salamanders are not a very large group or as varied as some of the other groups, but they have many points of extreme interest. Only one species reaches any great size, and that is the great Japanese salamander (Fig. 130), which may be as much as four feet long. The smallest is a tiny wraith of about one and a half inches, found in the forest above Vera Cruz in Mexico. I have already spoken (p. 71) of the loss of lungs in connection with forms developed in mountain brooks, where on account of its inevitable hydrostatic function the lung was so detrimental that the function of breathing is taken over by the wet skin. Limbs may also be lost, and the method of digit reduction and of limb reduction in Urodeles parallels most strikingly the same losses as seen in lizards (Figs. 131 and 132).

While in general no change in color occurs among reptiles and amphibians during the breeding season, some of the newts assume a gaudy nuptial dress (Fig. 133), which is left off or rather resorbed when the spring passes into summer. But in general there is no such beauty of color as many frogs exhibit at all seasons.

While the salamanders show no such peculiar developments in breeding habits comparable with the enormous variety seen among frogs and toads, there are one or two points of interest, for in many forms fertilization of the eggs takes place externally after the manner of fishes, while in others the spermatozoa issue from the male in curious little capsules called spermatophores. These are

picked up by the female with the enlarged and sensitive lips of the cloaca and are stored in a special pouch until the time comes for the fertilization of the eggs, a function which in such a case takes place internally.

Among the Urodeles are some very peculiar cave-dwelling types. We know of blind insects and blind crustaceans. The latter are well represented in Cuba where caves in the limestone occur in all parts of the island. The blind shrimps of the genus Palæmonetes are pure white with long spindly legs and antennæ; white also are the cave sow bugs or isopods (Cirolana), but one shrimp — *Barbouria poeyi* — is not white at all. This is a member of the marine family Hippolitidæ, and the only one which has taken to cavern life. It is a rich deep crimson of exactly the hue shown by many of the crustaceans found in the abysmal depths of the sea. The other cave crustaceans of Cuba have been derived from species living in fresh water, but the Cuban blind fish (Lucifuga and Stygicola) have had marine ancestors also. The fish are white, instead of colored like so many deep-sea fish. Barbouria, of all cave types, is brilliantly pigmented, and one can but wonder if it reached the caves by some means of ingress or passage which led directly to very deep water.

There are blind fishes in North America also, while blind salamanders occur in this continent and in Austria only, strange, spindle-shanked, pallid creatures, with legs in one form thinned out to serve as feelers. These salamanders lead as colorless an existence as can well be imagined. No reptiles have been long enough in caves to become much modified so far as we know, with possibly the single exception of a group of individuals of *Coluber tæniurus*. This species inhabits the great Batu Caves in Selangor in the Malay Peninsula and seems to be losing

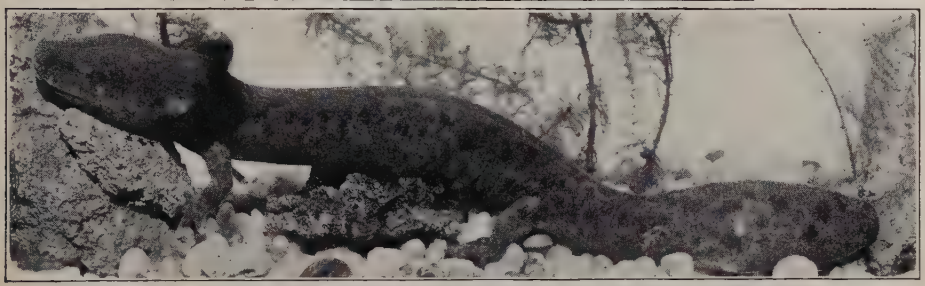


FIG. 133. MALE AND FEMALE OF A EUROPEAN SPECIES OF TRITURUS
The male has the nuptial crests assumed during the breeding season.

FIG. 134. NECTURUS, THE MUD PUPPY, WITH EXTERNAL GILLS WHICH IT CARRIES THROUGH LIFE

FIG. 135. THE WELL KNOWN 'AXOLOTL,' AN EDIBLE AMPHIBIAN FROM THE LAKES NEAR MEXICO CITY

This species may transform into a terrestrial salamander or may persist as a larva, breeding in that condition. In transformation the gills are resorbed, the gill clefts close, and the creature breathes air into his lungs.

FIGS. 136–138. ICHTHYOPHIS FROM CEYLON: AN EGG CLUSTER, A GILLED LARVA, AND A BROODING ADULT

FIG. 139. A LIVING COACH-WHIP SNAKE IN FLORIDA
A small example of a species reaching about eight feet in length.

FIG. 140. COMMON WATER SNAKE, MASSACHUSETTS, ABOUT THREE FEET LONG

color. The Malays call this the Ular Bulan or Moon Snake, and it feeds entirely on bats, as does also the Cuban Boa. These snakes haunt the mouths of caves, snapping at the stream of bats which emerge at dusk and reënter at dawn.

Urodele amphibians exhibit occasionally a curious characteristic called neoteny; that is assuming sexual maturity during larval life. The edible axolotls of the lakes near Mexico City, often sold in the markets, are 'permanent larvæ' (Fig. 135) and breed regularly in the gilled stage, never apparently transforming. These axolotls have been shipped to European zoölogical gardens and laboratories and are familiar to all naturalists. Yale University, however, found on having 'axolotls' sent from certain lakes in New Mexico that the mere capture and shipment was a sufficient stimulus or perhaps shock, so that they began to transform at once and on reaching New Haven soon assumed the adult or Ambystoma form. These are, indeed, Ambystomas closely related to familiar species of our Eastern States which invariably mature completely after a short larval life.

It is difficult to see why the axolotls of the Mexican lakes should be truly perennibranchiate when other transforming species live all about them. Even stranger are those New Mexican individuals which probably rarely assume the adult when undisturbed, but when captured promptly transform, while our common tiger salamander of New England, a very close ally, invariably transforms after a short larval life. The ordinary mud puppy or necturus (Fig. 134) has permanent gills, but there they are characteristic of the adults of the group [1] to which it belongs.

Cœcilians. At first sight cœcilians resemble earthworms, and some sixty or seventy species are known to live in mud

[1] The Perennibranchiate Urodeles.

and swamps in almost all of the equatorial countries, as well as in many of the islands of the Indian Ocean. The life-history of only one is even moderately well known, and this one is Ichthyophis (Figs. 136–38), of Ceylon. This genus has been studied by the Sarasin brothers, who have found that the nest is made and the eggs are brooded by the mother. The young on emerging pass from the muddy banks of the brook, where the eggs are laid, to the swift waters of the stream, where they take up for a time a wholly aquatic life. How they transform is not known.

One curious genus, Typhlonectes, looking almost like an eel, is found in some of the great rivers of South America.

CHAPTER XIV

SUPERSTITIONS

Let us now dwell for a moment upon a few common superstitions connected with snakes and amphibians. It is a pity that the folk-lore of some of these myths and superstitions cannot be analyzed. Do snakes fascinate birds and mammals and at times even man, to enable them to bite (not 'sting') or devour them the more easily? This is, of course, wholly a fallacy. A squirrel may sometimes be so terrified on finding itself near a snake that it becomes motionless through fear, but even this is doubtful.

On the whole, mesmerism is less proved than is the story that snakes swallow their young. No scientific observer has as yet seen and recorded the latter feat, although it has been seen by a friend of almost everybody outside of this class, and by many of their friends. Many snakes often contain living young simply because, though regularly egg-laying, they may retain the eggs until these are hatched, so that the young are thus born alive and may rupture the egg membrane a while before birth. If young snakes ever were swallowed for protective purposes, there would have to be some way of temporarily turning off the excessively active digestive fluid.

That salamanders could withstand fire was believed by the ancient Greeks. The fabulous hoop snake, which takes its tail in its mouth and rolls away downhill, or chases its victim, removing the tip of its tail from time to time only to prod the pursued, is a myth more local and doubtless more modern. In the southern Appalachian highlands the mountaineers believe that the coach-whip

snake (Fig. 139) wraps itself about a man and a tree, thus holding the man fast, while it proceeds to flog him to death with its tail, pushing the end of it into his nostrils from time to time as a means of finding out whether or not the victim has finally lost consciousness. Sea serpents and snakes milking cows tempt one to more digression.

Every voyager to the East has seen snake charming by Hindus (Figs. 141 and 142). These people have an uncanny way of knowing the places frequented by snakes, but though a very famous charmer went out with me near Lucknow, he never made any snakes appear, but simply hunted them as any one would have done. We rode by one village where the natives complained bitterly of a big cobra which they dared not kill on account of their superstition. They showed us the hole where he lived, and we dug him out. When he appeared he was a very splendid sight, and in the bright sunlight we secured a very remarkable photograph.

Snakes sometimes become tame through handling; also their mouths can be most inconspicuously sewed up, or injured or burned so that they dare not open them to bite. Jaws can be cut out, thus removing the fangs, and still the snakes may live for some time. The author could not observe any effect whatsoever of music; the old saying, 'as deaf as an adder,' seems pretty true.

FIG. 141. A SNAKE CHARMER OF JEYPORE, INDIA

FIG. 142. SNAKE CHARMERS OF BENARES WITH SNAKES OF SEVERAL SPECIES

CHAPTER XV

THE WORK OF EVOLUTION

It is an obvious fact that evolution has run riot in experimenting with the forms of reptiles and amphibians, but it is working obviously at varying rates of speed in different groups and it has acted independently on the larval and the adult life in many forms.

The material in our museums as well as our field studies enable us every day to point out with increasing certainty the exact path and even the rate of speed traveled by evolution in each group of the animal kingdom. One great factor, however, is still unknown; that is, the motive power. The one thing which neither Darwin nor any one else has really explained satisfactorily is the very title which Darwin took for his great book — 'The Origin of Species.' The survival of a species he made clear; he showed how gradual modification may come about, and he emphasized, in defining natural selection, one of the ways by which modifications may be influenced and intensified. But the appearance of wholly new characters having no selectional value until well developed is still ill-explained. The mutation theory is obviously inadequate, for the hitherto known or proved mutations are really very trivial. So also the sum total of the host of experiments carried on by most skilled observers, working perforce with domesticated animals under wholly unnatural conditions, has not as yet led very far. Some interesting and curious facts have been gleaned concerning especially the independence of germinal and somatic tissue and the working of laws of heredity, but the new confirmatory information obtained

is small compared with the great bulk of data which the systematists and the palæontologists have obtained. They must be the real guides in the maze, helping to point out clearly its intricate paths. If only either could learn the nature of the motive force of evolution! If only great facilities to breed wild species under natural conditions for great periods of time were thinkable! The trouble would be the time element — for time would have to pass with the word used in its geologic sense — very long periods of time indeed. Then the experimenter would probably choose mammals to work with, and the sun of the Age of Mammals is now fast setting before advancing civilization. The chance will pass before facilities are available, and we probably know to-day as much as we are ever likely to know regarding the major factors of evolution. Thousands of details will be fitted in and the habit of the ancestral tree will be increasingly well defined, but there will always remain the mystery. This will not be dispelled by complicated verbiage, and strange formulæ regarding the action, reaction, and interaction of more or less completely unknown forces serve only further to cloud a subject already far from clear. No reasonable person doubts the facts, but all are still in the dark as to the character of the underlying impetus.

Tate Regan, of the British Museum, has summed up the present position of Darwinism in a short but very masterly paper from which the following quotation is made:

> This theory [i.e., the mutation theory], which explains adaptation as the result of a series of fortunate accidents, appears to me to approximate to the old 'special creation' theory, and it was in opposing this idea of great and sudden transformations that Darwin wrote ('Origin of Species,' ed. 6, 1895, p.

191): 'To admit all this is, as it seems to me, to enter into the realms of miracle and to leave those of science.'

The mutation theory is in favour with the geneticists, who have found that definite variations occur and are definitely inherited. But the geneticists are puzzled to suggest how these variations could become specific characters, common to all the members of a species, seeing that they are not adaptive, and therefore could not be selected.

Systematists attach little importance to interspecific sterility; they know that Darwin showed that between allied species there are all gradations, from complete sterility to complete fertility. But for the geneticists sterility is all important — it is their one hope of producing the semblance of a species — and they proclaim that the event for which they are waiting is the production of a variety which is sterile with the parent form. That great event, if and when it occurs, will leave me cold; in my opinion, it will have about as much relation to the origin of species as the occurrence of albinos has to the coloration of arctic animals — that is to say, no relation whatever!

My own work on the structure, classification, and geographical distribution of fishes . . . has led me to certain conclusions. I believe that the first step in the origin of a new species is not a change of structure, but the formation of a community, either through localization, geographical isolation, or habitudinal segregation. I also think that specific characters may be grouped as follows: they are either (*a*) useful, (*b*) correlated with useful characters, (*c*) due to the environment, or (*d*) the expression of some physiological peculiarity. But I see no reason for believing that they have originated as mutations.

Here Regan practically restates 'Jordan's Law' of evolution through isolation, a most valuable postulate regarding the way by which forms evolve, but just why the isolated community varies as a whole is of course the mystery still. Mr. Regan continues:

So much for the 'age and area' and 'mutation' theories; now, as to the present position of Darwinism. What is Darwinism? First of all, it is the theory of organic evolution. Darwin showed that the facts of structure, classification, development, geograph-

ical distribution, and geological succession of animals and plants were intelligible only if there had been evolution. He gave a new impulse to work in these branches, all of which has confirmed his conclusion, so that at the present day we are justified in saying that organic evolution is no longer a theory, but an established fact. In a more restricted sense, Darwinism is Darwin's theory as to how evolution had taken place, and, as very few people seem to read Darwin nowadays, I will give it in his own words. He wrote:

'I have now recapitulated the facts and considerations which have thoroughly convinced me that species have been modified, during a long course of descent. This has been effected chiefly through the natural selection of numerous successive, slight, favourable variations; aided in an important manner by the inherited effect of the use and disuse of parts; and in an unimportant manner, that is in relation to adaptive structures, whether past or present, by the direct action of external conditions and by variations which seem to us in our ignorance to arise spontaneously.'

After this, the author knows that the reader will agree with him in simply reiterating once more a tribute to the great master, whose inspired work has met so splendidly the test of time. Note particularly that, while Darwin believed that species have been modified through a long course of descent chiefly through the natural selection of slight favorable variations, he admits frankly that this has been aided in an important manner by the inherited effect of the use or disuse of parts. So Darwin, himself, listened to Lamarck, and while we may incline first toward selection and then to use and disuse in our varying appraisal of the relative importance of each, we must remember that Darwin considered them both, and he probably laid more stress on natural selection than he would, were he living today. This concept was the child of his own thought, of his own inspiration — not forgetting that it dawned upon Wallace independently and at the same time. Lamarck's

doctrine had, of course, been put into print years before. So, in spite of the swaying pendulum and varying opinions as to the means whereby evolution moves, the thing itself is no longer in question among intelligent men.

CHAPTER XVI

CONCLUSIONS

The author acknowledges with much gratitude assistance received from the staff of the New York Zoölogical Society in securing illustrations, and the most efficient help and coöperation of Mr. George Nelson, in charge of preparations for the Museum of Comparative Zoölogy. A very large proportion of the illustrations speak for his great skill as a photographer. Figure 140 is particularly fine. The beautiful figures of species from the Congo are owed to Mr. Lang, of the American Museum of Natural History, who collected there for six years.

While bird photography has reached a high degree of perfection within recent years, the lack of interest in reptiles and amphibians and the curious prejudice inherent in the minds of most people have caused the field study of these animals to lag far behind, but an enormous amount might be accomplished by the painstaking observer who would interest himself in studying the life-history of even our most common species. Hibernation and the intimate life of many of these are very little known. The great difficulty is that reptiles appear and disappear in different years and in different localities in a most surprising way, and reptile hunting, even by the most skilled collector, is to a great degree a matter of chance. However, it is earnestly commended to the consideration of those readers who like to fare afield, that there is much of interest and value to be learned from the study of our cold-blooded neighbors.

ANNOTATED BIBLIOGRAPHY

ANNOTATED BIBLIOGRAPHY

This bibliography contains only hints for those who wish to become initiated into the study of herpetology. It is not intended to be an exhaustive list or to include any but a small selection of the more or less recent and general treatises upon the subject. Most of the books are available in any large public library, and all will be found in the library of any of the principal Museums of Natural History. In the British Museum *Catalogues* and the *Zoölogical Record* most of the references to herpetological literature may be found.

Gadow, Hans. *Amphibia and Reptiles.* The Cambridge Natural History. London, Macmillan & Co. Ltd., 1901.

The best anatomical and systematic treatise which has appeared. Those who have no anatomical foundation must be referred to one of the now many introductory manuals on the subject. To such beginners the two text-books following will be found most serviceable.

Wiedersheim, Robert. *Vergleichende Anatomie der Wirbelthiere.* 5th edition. Jena, Gustav Fischer, 1902.

Parker and Haswell. *A Text-Book of Zoölogy.* Vol. II. London, Macmillan & Co. Ltd., 1910.

For the student who may become interested in systematic herpetology the Catalogues of Snakes, Lizards, Chelonians, etc., and Amphibia in the British Museum, prepared by George A. Boulenger, will be the natural basis for any work. These volumes vary somewhat in treatment. Little or no account is taken of subspecies or geographic races, the nomenclature is not according to the International Zoölogical Code and many valid species are relegated to synonymy. Nevertheless, they are the most valuable works which have ever been written. The latest editions comprise nine volumes as follows:

Catalogue of Batrachia Gradientia. London, 1882.

Catalogue of Batrachia Salientia. London, 1882.

Catalogue of Chelonians, etc. London, 1889.
Catalogue of Lizards. Vols. 1–3. London, 1885, 1885, 1887.
Catalogue of Snakes. Vols. 1–3. London, 1893, 1894, 1896.

The *Zoölogical Record*, section on Reptiles and Amphibians, which appears annually from the Zoölogical Society of London, lists the papers that have appeared each year as well as the new forms named. They are an invaluable supplement to the British Museum Catalogues.

Nieden, Fr. Anura I. *Das Tierreich*, Heft 46. Berlin and Leipzig, Walter de Gruyter & Co., 1923.
This great volume purports to describe all the arciferous frogs and toads. It is, however, uncritical, incomplete, and should be used with care.

Two popular accounts of reptiles and amphibians have appeared:
Boulenger, E. G. *Reptiles and Batrachians*. London, J. M. Dent & Sons, Ltd. No date.
This is based largely upon observations in the London Zoological Gardens.

Ditmars, R. L. *Reptiles of the World*. 2d edition. New York, Sturgis and Walton, 1910.
This book, by the Curator of Reptiles for the New York Zoological Society, contains many observations made both in the field and in the Reptile House in the New York Zoölogical Park.

Since the great majority of recent works are faunal or geographic in scope, it may be useful to group these according to the area treated.

North America

Stejneger and Barbour. *A Check List of North American Amphibians and Reptiles*. 2d edition. Cambridge, Harvard University Press, 1923.
This gives the nomenclature in present use and an outline of the distribution of all the North American species.

Cope, E. D. *The Batrachia of North America.* Bull. U.S. Nat. Mus. No. 34. Washington, 1889.

This volume prepared by Professor Cope, using largely the manuscript of Spencer F. Baird, is most useful, especially whenever Baird's handwork is to be presumed.

Cope, E. D. *The Crocodilians, Lizards and Snakes of North America.* Annual Report of the U.S. Nat. Mus. for 1898. Washington, 1900.

A ponderous work testifying at once to the extremely nice taxonomic sense of its writer, his extraordinary grasp of reptilian comparative anatomy, and his utter carelessness in citation and reference.

Van Denburgh, John. *The Reptiles of Western North America.* Vols. 1–2. San Francisco, California Acad. of Sciences, 1922.

A somewhat expanded work, tolerably illustrated, which represents the extreme tendency to recognize and name localized variants. An extremely useful manual none the less.

Dickerson, Mary C. *The Frog Book.* North American Frogs and Toads, with a study of the Habits and Life-Histories of those of the Northeastern States. New York, Doubleday, Page & Co., 1906.

A splendid book. Full of original observations, it is both well written and excellently illustrated.

Ditmars, Raymond Lee. *The Reptile Book.* A comprehensive, popularized work on the structure and habits of the turtles, tortoises, crocodilians, lizards, and snakes which inhabit the United States and Northern Mexico. New York, Doubleday, Page & Co., 1907.

West Indies

Barbour, T. *A Contribution to the Herpetology of the West Indies.* Mem. Mus. Comp. Zoöl., Cambridge, Mass., Vol. 44, No. 2, 1914.

An attempt, now rather out of date, to list the West Indian species and cite references to descriptions of the species.

Stejneger, Leonhard. *The Herpetology of Porto Rico.* Ann. Rep. U.S. Nat. Mus. for 1902. Washington, 1904.

Barbour, T., and Ramsden, C. T. *The Herpetology of Cuba.* Mem. Mus. Comp. Zoöl., Cambridge, Vol. 47, No. 2, 1919.

Central and South America

No recent or satisfactory works have appeared which list the species of more than small areas of those great regions, still very incompletely known. The information is mostly to be found in a myriad of scattered papers. Here again the British Museum Catalogues will prove helpful.

Europe

Boulenger, G. A. *The Snakes of Europe.* London, Methuen & Co., Ltd. No date.

The model of its kind; complete and charmingly written.

Boulenger, G. A. *The Tailless Batrachians of Europe.* Parts 1–2. London, printed for the Ray Society, 1897.

Complete and giving a vast fund of information on life-histories and affinities.

Boulenger, G. A. *A Monograph of the Lacertidæ.* Vols. 1–2. London, British Museum, 1920–21.

Most European lizards are lacertids and are exhaustively treated in this remarkable work. Unfortunately, individual aberrations and geographic variants are not considered as separate categories

A general work on European lizards and one on the salamanders are much to be desired.

India

Boulenger, G. A. *Reptilia and Batrachia.* The Fauna of British India including Ceylon and Burma. London, Taylor & Francis, 1890.

Useful keys, but descriptions which take little or no account of individual variation, make this volume somewhat difficult to use.

Wall, F. *The Snakes of Ceylon.* Colombo, Government Printer, 1921.

A remarkably full and exhaustive work, the only criticism being the undue multiplication of genera. Breeding habits, feeding, venom, treatment of snake bite, and many other matters are well covered.

Nicholson, Edw. *Indian Snakes.* An elementary treatise on ophiology. Madras, Higginbothem & Co., 1874.

Contains excellent figures and much valuable information.

British Malaya

Boulenger, G. A. *Reptilia and Batrachia.* A vertebrate fauna of the Malay Peninsula London, Taylor & Francis, 1912.

A useful compilation, the descriptions largely culled from the British Museum Catalogues and containing but little concerning habits or abundance.

Siam

Numerous papers by Dr. Malcolm Smith in the publications of the Natural History Society of Siam at Bangkok discuss most of the reptiles and amphibians of this area. The sea snakes and tadpoles have had Dr. Smith's especial attention.

Netherlands East Indies

De Rooij, Nelly. I. *Lacertilia, Chelonia, Emydosauria.* The reptiles of the Indo-Australian Archipelago. Leyden, Brill & Co., 1915.

A very complete account built on the basic methods of Boulenger's Malayan volume. The two following volumes complete the series.

De Rooij, Nelly. II. *Ophidia.* Leyden, Brill & Co., 1917.

Van Kampen, P. N. *The Amphibia of the Indo-Australian Archipelago.* Leyden, Brill & Co., 1923.

The Philippine Islands

Three papers describing the lizards, snakes, and amphibians of the Philippines have been written by Edward H. Taylor and

issued by the Bureau of Sciences of Manila in 1920–22. They are most serviceable, although there is possibly an undue multiplication of forms recognized.

Japan and Adjacent Territory

Stejneger, Leonhard. *The Herpetology of Japan and Adjacent Territory.* Bull. U.S. Nat. Mus., No. 58, Washington, 1907.

The most thorough and satisfactory faunal monograph upon reptiles that has ever been written.

Africa

Anderson, John. *Reptilia and Batrachia.* Zoölogy of Egypt. Vol. 1. London, Quaritch, 1898.

An excellent account albeit of a limited fauna.

Short papers with simple keys whereby most of the reptiles and amphibians inhabiting Africa south of the Sahara can be identified will be found in the *Proceedings* of the Zoölogical Society of London between 1917 and 1923. These were prepared by Dr. G. A. Boulenger.

Australia, China, Russia

No complete and modern accounts of the Australian fauna have appeared. The same is true of China, Central Asia, and Russia.

Zoögraphy

Several excellent accounts of the zoögraphical distribution of animal life have appeared which are available in most well-equipped public libraries. The following will be found of special interest:

Gadow, Hans. *The Wanderings of Animals.* Cambridge University Press and G. P. Putnam's Sons, New York.

This is a short, inexpensive, and readable discussion of the topic, designed especially for the student who has not yet acquired a wide knowledge of the terminology of systematic zoölogy.

Beddard, Frank E. *A Text-Book of Zoögeography*. Cambridge University Press, 1895.

This gives a good description of the several zoölogical regions and the characteristic faunistic peculiarities of each one.

Wallace, Alfred Russel. *The Geographical Distribution of Animals*. Vols. 1–2. London, Macmillan & Co.; New York, Harper & Bros., 1876.

This discussion 'of the relations of living and extinct faunas as elucidating the past changes of the earth's surface' is still a classic, although modern discovery has tended to modify many of the conclusions.

Wallace, Alfred Russel. *Island Life*. London, Macmillan & Co., 1880; New York, Harper & Bros., 1881. 2d and revised edition, Macmillan & Co., London and New York, 1892.

A most noteworthy account of the fauna of islands, pointing out the fundamental differences between those of continental and oceanic types, according as they have or have not been in geographic connection with the greater land masses.

Matthew, W. D. *Climate and Evolution*. Ann. N.Y. Acad. Sciences, Vol. 24, pp. 171–318, 1915.

The most critical and scholarly essay on the dispersal of animals that has ever appeared. The writer is perhaps over-conservative in declining to consider favorably interpretations of distribution involving much change in the present continental form. That such changes have taken place is now admitted by most modern geologists.

INDEX

Abbreviated life-histories in Amphibians, 82.
Abnormalities in reptiles, 52.
Acanthophis, 25.
Acanthophis antarcticus, 25.
Acknowledgments, 108.
adamanteus, Crotalus, 12, 35.
Adaptations of frogs, 69; of lizards, 53.
Adder, Death, 22, 25.
Spreading, 47.
æsopus, Rana, 96.
African Tree Viper, 43.
Agalychnis, nesting of, 81.
Agama, dichromatism in, 68.
Agamidæ, 55, 64; teeth, 38.
Age and area, 105.
Agkistrodon rhodostoma, 25.
Alligators, egg-laying of, 61; size, 12; species of, 9.
Alytes obstetricans, 76, 81.
Amblycephalus, food of, 39.
Amblyrhynchus, 5.
Ambystoma, form of axolotl, 99.
Amphibians, horned, 92; methods of feeding in, 94; origin and distribution, 1; poisonous species of, 90; species of, 9; superstitions about, 101; voices of, 95; warning colors and postures in, 92.
Amphignathodon, brood pouch in, 89.
Amphignathodontidæ, 87.
Anaconda, size, 11.
Anguidæ, 60.
Anoles, 60.
Anolis, 7, 8; dewlap in, 67; dichromatism in, 68.
antarcticus, Acanthophis, 25.
Ant-eating toads, 73.
Anura, fossil, 3.
Apostolepis, mimicry in, 49.
Aquatic adaptations of frogs, 72; of reptiles, 51.
Aquatic frogs of the Andes, 70.
Aristelliger, 61.
Arthroleptis seychellensis, parental care in, 83.
Atelopus stelzneri, 82.
Atheris, 43.
atrox, Bothrops, 24, 26.
auriculatus, Eleutherodactylus, 83.
Australian Blacksnake, 22; poison of, 34.
Axolotl, 99.

Barbouria poeyi, 98.
Barking Frog, voice of, 96.
Basiliscus, 53.
Basilisk, 53.
Batrachichthys, 75.
Batrachophrynus, 71.
microphthalmus, 72.
Bats eaten by snakes, 99.
Bibliography, 111.
Bipedal locomotion of lizards, 54.
Bird enemies of snakes, 28.
Black Snake, habits, 46.
Snake, Australian, 22, 34.
Blind salamanders, 98.
Worm, 60.
Boa, Cuban, 99.
Boas, coiling of, 46.
Bolitoglossa, 95.
Bombina, defensive action of, 93.
Boodon, 29.
Bothrops, 23.
atrox, 24, 26.
insularis, 23; toxicity, 23.
jararaca, toxicity, 24.
Box tortoise, 7.
Brazil, snake bites in, 19.
brevirostris, Hylambates, 82, 86.
Brooksia, 56.
Bufo empusus, 74.
Bufonidæ, 88; Tree Toads of family, 77.
Bungarus, 22; venom of, 36.

Burrowing habits of amphibians, 73.
Burrowing snakes, 45.
Bushmaster, size, 12; action of venom, 37.

Calabaria, 44.
Causus, 25; poison glands of, 49.
Cave-dwelling salamanders, 98.
Cayman, 9.
Cerastes, 51.
Cerathyla, development of, 88.
Ceratophrys, defensive action of, 93.
Chamæleo, 56.
Chamæleon, adaptations of, 56; color changes in, 64, 65.
Chamæleon, Florida, 8.
Chicken Snake, 46.
chilensis, Conepatus, 27.
Chiromantis, 79.
Chlamydophorus, 74.
Chlamydosaurus, 54.
Chrysopelea, 52.
Cirolana, 98.
Clawed frogs, 72.
Clelia clœlia, 28.
Cobra, 21, 22, 30; action of venom, 36; spitting of venom, 43; venom, 34.
Indian, 47.
King, 27; size of, 11.
Tree, 22.
Cœcilians, 97, 99; species of, 10.
Coloration of snakes, 50; protective, 43.
Coluber tæniurus, 98.
Common Toad, 94.
Conclusions, 108.
Conepatus chilensis, 27.
suffocans, 27.
Conolophus, 53.
Control of poisonous snakes, 25.
Coral Snake, 30.
Corn Snake, 46.
Cricosaura, 8.
Crocodiles, egg laying of, 61; odor of, 45; size, 13; species of, 9.
Crocodilians, ancient distribution, 6.
Crotalus, rattle of, 40.
adamanteus, 12; venom, 35.
terrificus, venom, 35.
Cryptobatrachus fuhrmannii, brooding of, 87.
Cuban blind fish, 98.
Boa, 99.
culeus, Telmatobius, 70.
Cyclophis, 43.
Cylindrophis, mimicry in, 49, 50.
Cystignathidæ, 87.

Dagger Frog, 75; defensive action of, 93.
darwini, Rhinoderma, 85.
Darwinism, present position of, 104.
Dasypeltis, 32.
Death Adder, 22, 25.
Death-feigning, 94.
Deiroptyx, diving habits, 54.
Dendraspis, 11.
Dendrobates, parental care in, 83.
tinctorius, poison of, 93.
Desert lizards, adaptations of, 55.
Desert Rattlesnake, 92.
Dewlap of lizards, 66.
Diamond-back Terrapin, 17.
Dichromatism, Sexual, 68.
Dinosaurs, former distribution of, 4.
Dipsosaurus, 55.
Dispholidus, 49.
Doliophis, 25.
Doliophis intestinalis, 49, 50.
Double tail in lizards, 52.
Double-headedness, 52.
Draco, habits of, 64.
Dryiophis, 46.
Duckbill, poison of, 90.

Egg-laying of reptiles, 60.
Elaphe, 46.
Elapidæ, 21, 30; fangs, 31; venom, 35.
Elaps, 30.
fulvius, 22.
Eleutherodactylus auriculatus, development, 83.
inoptatus, 96.
latrans, 96.
luteolus, use of slime by, 79.
martinicensis, development, 83.

empusus, Bufo, 74.
Eryx, 44.
evansi, Hyla, 87.
Evolution, 103; through isolation, 105.
exanthematicus, Varanus, 94.

faber, Hyla, 78.
Fang, origin and use, 29.
Feeding habits of reptiles, 38.
Feeding methods of amphibians, 94.
Fer-de-lance, 23, 24, 28; action of venom, 37.
Fertilization in tailless amphibians, 80.
Florida chamæleon, 8.
Flying Frog, 62.
Gecko, 61, 62.
lizards, 62.
Snake, 52.
Food value of reptiles, 15.
Frilled Lizard, 54.
Frog, largest, 14; smallest, 14.
Frog, Barking, 96.
Dagger, 75, 93.
Gopher, 96.
Hairy, 75.
Horned, 93.
Horned Tree, 88.
Paradoxical, 75.
Frogs, adaptations of, 69; method of feeding in, 94; nesting habits of, 77; voices of, 95.
fuhrmannii, Cryptobatrachus, 87.
fulvius, Elaps, 22.
fuscomaculata, Paludicola, 79.

Gaboon viper, 24.
Gampsosteonyx, 76.
Gecko, Flying, 61, 62.
Geckos, adaptations of, 57; egg-laying, 60; eyes, 58; feet, 58; habits, 58; voice, 58; self-mutilation, 59.
Gekkonidæ, 54, 57.
getulus, Lampropeltis, 27.
Giant Land Tortoise, 12, 16.
Toads, defensive action, 93.
Gigantosaurus, 4.
Gila Monster, 65; poison of, 65; spitting of venom by, 43.
Glass Snake, 60.
goeldii, Hyla, 87.
goliath, Rana, 14.
Gopher Frog, cry of, 96.
Green Iguana, 15.
Turtle, capture, 15.
Ground Boas, protective habits, 44.
Ground Racers, 46.

Hæmolytic poison, 35.
Hairy Frog, 75.
Hamadryas hannah, 11.
hannah, Hamadryas, 11.
Hawksbill Turtle, 16.
Hedgehog, 27.
Heloderma, 65, 90.
horridum, 43, 65, 66.
suspectum, 65.
Helodermatidæ, 65.
Heterodon, 47.
Hippolitidæ, 98.
hochstetteri, Liopelma, 85.
Hog-nosed Snake, 47; death-feigning by, 94.
Hoop Snake, 101.
Horned amphibians, 92.
Frog, defensive action of, 93.
reptiles, 51, 92.
Toad, 55; ejection of blood by, 66.
Tree Frog, 88.
Horns in reptiles, 51, 92.
horridum, Heloderma, 43, 65, 66.
Hydrophidæ, 30, 51.
Hyla evansi, brooding of, 87.
faber, 78.
goeldii, brooding of, 87.
resinifictrix, 78.
rosenbergi, 78.
vasta, skin poison of, 92.
Hylambates, 77.
brevirostris, 86, 90; brooding of, 82.
Hylidæ, 69, 78, 87.
Hymenochirus, 72.

Ichthyophis, habits of, 100.
India, snake bites in, 20.
Indian Cobra, 47.
Iguana, dichromatism in, 68.

Iguana, Green 15.
Marine, of Galapagos, 5, 53.
Iguanidæ, 53, 54, 55; dewlap in, 66.
Inflation by snakes, 47.
inoptatus, Eleutherodactylus, 96.
insularis, Bothrops, 23.
Island frogs, adaptations of, 84.

Japanese Salamander, 97.
Tree Frog, egg-laying of, 80.
jararaca, Bothrops, 24.
Jordan's law, 105.

King Cobra, 27; size of, 11.
Snake, 27.
komodoensis, Varanus, 8, 12.
Krait, 22; action of venom, 36.

Lachesis muta, 12.
Læmanctus, 53.
Lampropeltis getulus, 27.
Land bridges, 6.
Land Tortoise, Giant, 12, 16.
Langaha, 46.
Lanthanotus, 65.
Larval stage, suppression of, in frogs, 85.
latrans, Eleutherodactylus, 96.
Leather-back Turtle, weight, 12.
Legless lizards, 9.
Lepidoblepharis sanctæ-martæ, 14.
Leptodactylidæ, 78, 79; brooding habits of, 88.
Leptodactylus, 96.
mystacinus, 79.
ocellatus, 78.
Leptotyphlopidæ, 39; habits of, 45.
Leptotyphlops, 14.
leucomystax, Polypedates, 80.
Lichanura, 44.
Life-histories, abbreviated, 82.
Limb reduction in Urodeles, 97.
Limbs, reduction of, 55.
Liolepis, 38, 55.
Liopelma hochstetteri, development of, 85.
Lizard, Frilled, 54.
Lizard, largest, 12; smallest, 14.
Lizards, bipedal locomotion in, 54; dewlap of, 66; as reservoirs for disease parasites, 66; poisonous species of, 65; protective devices in, 64; reduction of limbs in, 55; species of, 9.
Loggerhead Turtle, 16.
Lucifuga, 98.
Lungless salamanders, 71.
luteolus, Eleutherodactylus, 79.
Lygodactylus, 57.
Lytorhynchus, 45.

Mamba, 11, 22; inflating habit of, 48.
Marine Iguana, 53.
martinicensis, Eleutherodactylus, 83.
Megalophrys, 77; horns in, 92.
microphthalmus, Batrachophrynus, 72.
Telmatobius, 71.
Micrurus, 30.
Midwife Toad, 81.
Mimicry in snakes, 49.
Miodon, 30.
Moloch, 55, 66.
Momentum in evolution, 63.
Mongoose, introduction of, 26.
Monitor, 8.
Monster, Gila, 43.
Moon Snake, 99.
Mud puppy, 99.
Musurana, 27, 28.
muta, Lachesis, 12.
Mutation theory, 103, 104.
Myrmecophagy, 73.
mystacinus, Leptodactylus, 79.

Naia, 23.
naia, 47.
nasicornis, Vipera, 51.
Nectophryne, egg-hatching in, 82.
Necturus, 99.
Neoseps, 55.
Neoteny in urodeles, 99.
Nesting habits of frogs and toads, 77.
Neurotoxic poison, 34.
Newts, nuptial colors in, 97; Tertiary fossils of, 3.
nigricans, Phryniscus, 82.
nigropalmatus, Polypedates, 62.
niloticus, Varanus, 8.
Nocturnal habits, 8.

Nototrema, brood pouch in, 89.
Number of species, 9.

obstetricans, Alytes, 76, 81.
ocellatus, Leptodactylus, 78.
Odor, protective, of snakes, 44.
Onychodactylus, 72.
Ophiodrys, 43.
opisthodon, Rana, 84.
Opposable thumb in amphibians, 75.
Origin of reptiles and amphibians, 1; of species, 103.
Ornithorhynchus, poison spine of, 90.
Ovoviviparity, 82.
Oxybelis, 46.

Palæmonetes, 98.
Palmatogecko, 59.
Paludicola fuscomaculata, 79.
Paradoxical frog, 75.
Parrots, particolored, and frog poison, 95.
Pelamydrus platurus, 23.
Phragmosis, 73.
Phryniscus nigricans, transformation of, 82.
Phrynosoma, 55; ejection of blood by, 66.
Phyllobates, parental care in, 83.
limbatus, 14.
Phyllomedusa, 81; nest of, 80.
Phyllorhynchus, 45.
Phyllurus, 59.
Pichiciego, 74.
Pilot Black Snake, 46.
Pipa, 72.
pipa, 87.
Pit vipers, 22.
Placentation, attempts at, in amphibians, 89.
platurus, Pelamydrus, 23.
Plesiosaurs, 5.
poeyi, Barbouria, 98.
Poison of amphibians, 91; of reptiles, 33; action of, 34.
Poisonous amphibians, 90; lizards, 65; snakes, 19; control of, 25.
Polyodontophis, 29.
Polypedates, 77; brooding of, 87.
Polypedates, leucomystax, egg-laying of, 80.
nigropalmatus, 62.
schlegeli, egg-laying of, 80.
porphyriacus, Pseudechis, 34.
Protective adaptations in reptiles, 51.
coloration of snakes, 43.
devices in lizards, 64; in snakes, 40.
odor of snakes, 44.
Pseudechis porphyriacus, 34.
Pseudhymenochirus, 72.
Pseudis, 75.
Pseudoplacenta, 90.
Ptenopus, 54, 58.
Pterodactyls, 62.
Ptychozoon, 61.
Python, 46; brooding of, 61; size of, 11.

Racers, 46.
Rana æsopus, cry of, 96.
goliath, 14.
opisthodon, development of, 84.
Ranidæ, 70.
Rattle of rattlesnake, 40.
Rattlesnake, rattle of, 40; size of, 11, 12; spitting of poison by, 43.
Desert, 92.
Reduction of limbs, 55.
Reptiles, fossils forms of, 4; horned, 92; origin and distribution, 1.
resinifictrix, Hyla, 78.
Rhacophorus, 87.
Rhampholeon, 56.
Rhinoderma darwini, brooding of, 85, 90.
Rhiptoglossa, 56.
rhodostoma, Agkistrodon, 25.
Rhynchocephalia, 4.
River Jack, 51.
rosenbergi, Hyla, 78.
Russell's Viper, 21, 22; action of venom, 36; spitting of venom, 43.

Salamander and fire, 101.
Japanese, 97.
Tiger, 99.
Salamanders, 97; blind, 98; cave-

dwelling, 98; feeding habits of, 94; fertilization in, 97; loss of lungs in, 71.
Salvadora, 45.
sanctæ-martæ, Lepidoblepharis, 14.
Sand boas, protective habits, 44.
Sapo de concha, 74.
schlegeli, Polypedates, 80.
Schlegel's Viper, horns in, 92.
Scincidæ, 54.
Sea Snake, 22, 24, 30; nostrils of, 51.
Sepidon, 42.
Sexual dichromatism, 68.
Shell-headed Toad, 74.
Shrimps, cave-dwelling, 98.
Sibynomorphus, food of, 39.
Sidewinder, 92.
Sistrurus, 40.
Size of snakes, 11.
Skin modifications in amphibians, 69.
Skink, 7, 55; adaptations of, 56.
Skunk, protective odor of, 44; resistance to venom, 27.
Slime used by frogs, 79.
Snake, Chicken, 46.
Coral, 30.
Corn, 46.
Glass, 60.
Hog-nosed, 47, 94.
Hoop, 101.
King, 27.
Moon, 99.
Pilot Black, 46.
Sea, 22, 24, 30, 51.
Tiger, 22.
Snake bite, deaths from, 20.
Snake charming, 102.
Snake, smallest, 14.
Snakes, killing of by motors, 7; milking cows, 102; odor of, 44; protective devices of, 40; species of, 9; superstitions about, 101.
Snapping Turtle, as food, 17.
Sounds made by reptiles, 51.
Species, number of, 9.
Sphærodactylus, 60.
Sphenodon, 4, 10.
Spitting snakes, 42.
Spreading Adder, 47.
Spreading snakes, 47.
Stegocephalians, 3.
stelzneri, Atelopus, 82.
Sterility between species, 105.
Stygicola, 98.
suffocans, Conepatus, 27.
Superabundant growth force, 63.
Superstitions about snakes and amphibians, 101.
Surinam Toad, oviposition and brooding of, 86.
suspectum, Heloderma, 65.
Swallowing young by snakes, 101.

Tadpoles, 75, 77.
tæniurus, Coluber, 98.
Tails, use of in lizards, 59.
Telmatobius culeus, 70.
microphthalmus, 71.
Terrapin, Diamond-back, 17.
terrificus, Crotalus, 35.
Theletornis, inflating habit of, 47.
Tiger Salamander, 99.
Snake, 22.
tinctorius, Dendrobates, 93.
Toad, Common, 94.
Giant, 93.
Horned, 55.
Midwife, 81.
Shell-headed, 74.
Surinam, 86.
Wood, 82.
Toads and warts, 92; Ant-eating, 73; nesting habits of, 77.
Tookay, 58.
Tortoises, species of, 9.
Tree Cobra, 22.
Frog, Horned, 88.
Frogs, 69.
Snakes, 45.
Toads, 70.
Triceratops, 57.
Tropidophis, curling of, 44.
Tropidophorus, 54.
Turtle, Leather-back, weight, 12.
Snapping, as food, 17.
Turtle eggs, 17.
Turtles, species of, 9.
Typhlonectes, 100.

Typhlopidæ, 38; habits of, 45.

Uma, toes of, 54.
Urodeles, 97; limb reduction in, 97: loss of lungs in, 97; neoteny in, 99.
Uropeltidæ, 74.

Varanus exanthematicus, death-feigning by, 94.
komodoensis, 8, 12.
niloticus, 8.
vasta, Hyla, 92.
Viper, venom of, 35.
African Tree, 43.
Gaboon, 24.
Russell's, 21, 22, 36, 43.
Schlegel's, 92.
Vipera nasicornis, 51.
Vipers, Pit, 22.
Voices of amphibians, 95.

Warning colors in amphibians, 92.
postures in amphibians, 92.
Warts, 92.
Water Snake, double-headedness in, 52.
Whip-snakes, 43.
Wood Toad, egg-hatching in, 82.
Work of evolution, 103.

Xantusiidæ, 8.
Xenodon, 30.
Xenopus, 72.

Zonurus, 55.

NORTH CENTRAL COLLEGE
598.1823
C001
REPTILES AND AMPHIBIANS BOSTON
3 2611 00045853 5